

IN THIS ISSUE

Small college or university herbaria are an often unheralded resource that nevertheless may contain valuable collections that add to our knowledge or fill in gaps that remain after study from more comprehensive collections. They also may provide the best information on the flora of local regions. One such collection, housed at Manchester University in northeastern Indiana, is described in the first article, which discusses the history of the collection as well as of the university and highlights the careers of several of the important collectors represented in the collection.

Oak forests have historically covered much of the eastern United States, often maintained by fire. The second article by Robert Tatina examines one such old growth oak forest in southwestern Michigan to consider successional processes, including the effect of the absence of fire, and describes the changes the parcel is currently undergoing.

Summer algae classes at the University of Michigan Biological Station conducted over the years by Patrick Kociolek and Rex Lowe have made original explorations of the diatom floras of several localities in Michigan that have occasionally resulted in publications. The third paper is the latest of these, an exploration of the diatom flora of Torch Lake in Antrim County, Michigan, chosen specifically because of its oligotrophic nature. The paper enumerates the taxa found there, but more specifically presents taxonomic and distributional discoveries pertaining to several of those taxa, including the description of six new species and the report of three new records for the United States.

Patterned fens are an unusual community type with a decidedly northern distribution. They are peatlands that are characterized by alternating low and high vegetation zones arranged perpendicular to the flow of water and having a distinctive floristic composition. The fourth paper in this issue reports the discovery of first patterned fen in Michigan's Lower Peninsula and describes its vegetation and species composition, especially in comparison to other regional patterned fens, thereby highlighting the variability among such communities. Included also is a brief discussion of the formation of these communities.

This issue concludes with a brief memorial to the late Don C. Henson, well known to many members of the Michigan Botanical Club, that describes his extensive contributions to the botany of the Upper Peninsula as well as his artistic endeavors; a westward range extension of the lycopod *Dendrolycopodium obscurum* along with a clarification of the identity and distribution of that species and its relatives in Minnesota; and a book review of two large and beautifully illustrated coffee-table-sized books on the natural history of Minnesota.

—Michael Huft

MANCHESTER UNIVERSITY'S PLANT COLLECTION: AN IMPORTANT PLANT RESOURCE FOR NORTHEASTERN INDIANA

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ABSTRACT

Small plant collections are an essential resource for research in under-sampled or unknown areas. Manchester University (MU), located in Wabash County in northeastern Indiana, has a rich and lengthy history in the natural sciences and has housed a plant collection since the beginnings of the institution in 1889. Manchester University's plant collection holds 4,658 specimens spanning more than 1,546 species. 59.7% of the specimens were collected in Wabash County, Indiana, thereby providing an excellent sample of the flora of northeastern Indiana. The collection has specimens added by MU professors as well as by students and members of the community, making it a unique collection demographically. Manchester's plant collection houses specimens from relatively under-collected regions of Indiana that fills a gap in the distribution maps of many species in the state. In addition, it holds records of several species that are likely now extirpated from the area. This survey hopes to make this collection more accessible and to support an application to list this collection in Index Herbariorum. This would allow local conservation groups and researchers to expand their knowledge of northeastern Indiana's natural heritage.

KEYWORDS: Manchester University, plant collection, Wabash County, small herbaria, flora of northeastern Indiana

INTRODUCTION

Herbaria have long played an important role in the collective botanical knowledge of the scientific community. These collections of plants provide botanists with a systematic way to record the occurrence of species throughout space and time (Baird 2010). Herbaria play such a crucial role in our understanding of horticultural plants, the natural world, and economic plants that many institutions have spent large amounts of resources over the last four centuries in order to expand and catalog the world's plant diversity (Besnard et al.

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2018). However, not all botanical collections are this extensive and widely available to researchers. Many plant collections across the world are small herbaria that typically contain less than 10,000 specimens (Harris and Marsico 2017). Despite their modest size, these small herbaria are often the only records of plants in many localities, particularly areas that are rural and underserved by the scientific community.

Small herbaria provide essential running records of local flora that can be used by researchers to potentially evaluate genetic variation within a species over time (Cozzolino et al. 2006), analyze local patterns of extinction (McGraw 2001), and understand the impact humans have had on local plant communities (Lavoie 2012). Local herbaria also house records of historical plant distributions, which provide snapshots of the land and its conditions at different time periods. This information can be used by historians and ecologists to fill gaps in our knowledge of local history and to draw connections between people and the land they live on. Knowing what specimens an herbarium holds is essential to understanding the historical importance of an area and making valuable resources available to researchers to aid in their studies of broader environmental and conservation issues.

Faculty members at Manchester University, a small liberal arts university in Wabash County Indiana, have been collecting plants since the university's beginning in the late 1800s. By 1895, the university already housed 1,200 specimens in its collection. This collection consisted of a "nearly complete record of the flowering plants of Wabash county, including many specimens that were rare at the time" (Eberly 2005). The vascular plant collection has had significant additions since these initial collections. Manchester University's plant collection acts as a nearly complete catalog of local flora in northeast Indiana. It also houses collections from throughout Indiana, as well as the United States.

Despite being small, the collection at MU can still provide researchers and historians with an important look into Wabash County's ecological past. This collection houses many records for one of the most under-collected and undocumented areas of the Indiana flora. In particular, Wabash County has undergone tremendous land-use changes since the initial collections in the late 1800s. This under-collection of plant specimens is particularly concerning as northeast Indiana was dominated by forests before being converted to mainly agricultural land (80–90%) by European settlers (Hedge 1997; Radeloff et al. 2005). The plant collection likely hosts records for many plants that are now locally extirpated as well as county records that have been unexamined in major North American floristic studies.

The collection at MU is currently uncatalogued and is not recognized in *Index Herbariorum* (Thiers 2021) as an herbarium available for researchers to use. The plant collection likely represents a missing puzzle piece in the distribution of many species in the Indiana flora. Manchester University's collection would be the first and only recognized herbarium in Wabash County to be made accessible for research purposes, thereby providing this under-sampled area with a valuable scientific resource. In order to understand what MU could offer the scientific community, we completed a census of its vascular plant collections. In particular, we wanted to know who the major collectors were, to survey the geographic

area that the collection represents, and to understand the diversity held in the collection. This information will help contribute to the better understanding and historical distribution of plants in northeastern Indiana and will promote the better use of herbaria in local conservation efforts.

HISTORY OF THE NATURAL SCIENCES AT MANCHESTER UNIVERSITY

Manchester University is a small, private school in North Manchester, Indiana, a town roughly 40 miles from Fort Wayne in northeastern Indiana. The school was founded by the Church of the Brethren (with which it is still affiliated) in 1860 as Roanoke Classical Seminary in Roanoke, Indiana but did not officially become Manchester College until 1889 when the school was moved 30 miles west to the town of North Manchester (Manchester University 2020). Albert B. Ulrey (A.B. Ulrey) (Figure 1) was the first professor of the natural sciences to teach at Manchester, appearing on the class roster in 1891 teaching classes in botany, bacteriology, zoology, geology, and sanitation. Thanks to A.B. Ulrey and other collectors, the school had a modest plant collection in 1895 despite being such a young institution. According to a school catalog written in 1895, the herbarium at the school contained “about twelve hundred specimens.



FIGURE 1. A.B. Ulrey (ca. 1892), the first natural science professor from 1891 to 1900, started the plant collection at Manchester College. Photo provided by the Manchester University Archives and Peace Studies Church of the Brethren Collection, North Manchester, Indiana.

A considerable number of rarer plants are represented. A fairly complete collection of the vertebrates and flowering plants of Wabash County has been arranged in systematic order” (Eberly 2005).

As Manchester College grew through the late 1800s, more classes were added to the curriculum and more professors were welcomed to the faculty. It was also during this time that A.B. Ulrey and his colleagues were developing a modern science curriculum and standard at Manchester. Based on course descriptions from the beginning of the school, it appears that students spent most of their time in labs or out in the field, learning practical and applied science. Experience-based classes allowed professors and their students to spend time in the field collecting plant specimens rather than sitting for lectures. Many of the plants that were collected by the professors and their classes were likely studied before being incorporated into the plant collection. Ulrey and his classes were especially active, collecting much of the original herbarium in the late 1800s during his years at Manchester.

Manchester College grew steadily after Ulrey retired in 1900 as the faculty expanded and the school drew in more students. The College experienced exponential growth in 1932 when it merged with Mount Morris College, another Brethren-affiliated school in Mount Morris, Illinois. This merger brought in many new science professors, including O.W. Neher. Neher taught mainly botany and, following the tradition of field-based education at Manchester, led many excursions to nearby states such as Ohio and Kentucky where students learned plant features and distribution (Eberly 2005). Much as for Ulrey, these field experiences allowed O.W. Neher to collect plants to use in class as well as to add to the existing plant collection. After O.W. Neher retired from Manchester College, the professors who took up his position continued the tradition of experience-based education and added their own specimens to the steadily growing plant collection (see Important Collectors, below).

PLANT SPECIMENS HELD AT MANCHESTER UNIVERSITY

The Manchester University plant collection holds a total of 4,658 specimens that represent roughly 1,546 species. These specimens have all been entered into a publicly viewable database available at Manchester University (2021). The most frequently collected species in the collection are *Barbarea vulgaris* W.T. Aiton with 22 specimens and *Acer saccharum* Marshall with 20 specimens. The family with the largest number of specimens in the collection is the Asteraceae with a total of 651 specimens, followed by the Poaceae with 335 specimens (Figure 2). The taxonomy of the plant collection largely follows taxonomic concepts from the 1980s and 1990s. This precluded us from doing a more fine-grain analysis of the collections and will require some detailed updating of the plant collection specimens.

Of the 1,546 species represented in the plant collection at Manchester, 35 species, spanning 48 specimens, are on the Indiana state threatened and endangered species list (Table 1). Many of these specimens are from the Indiana

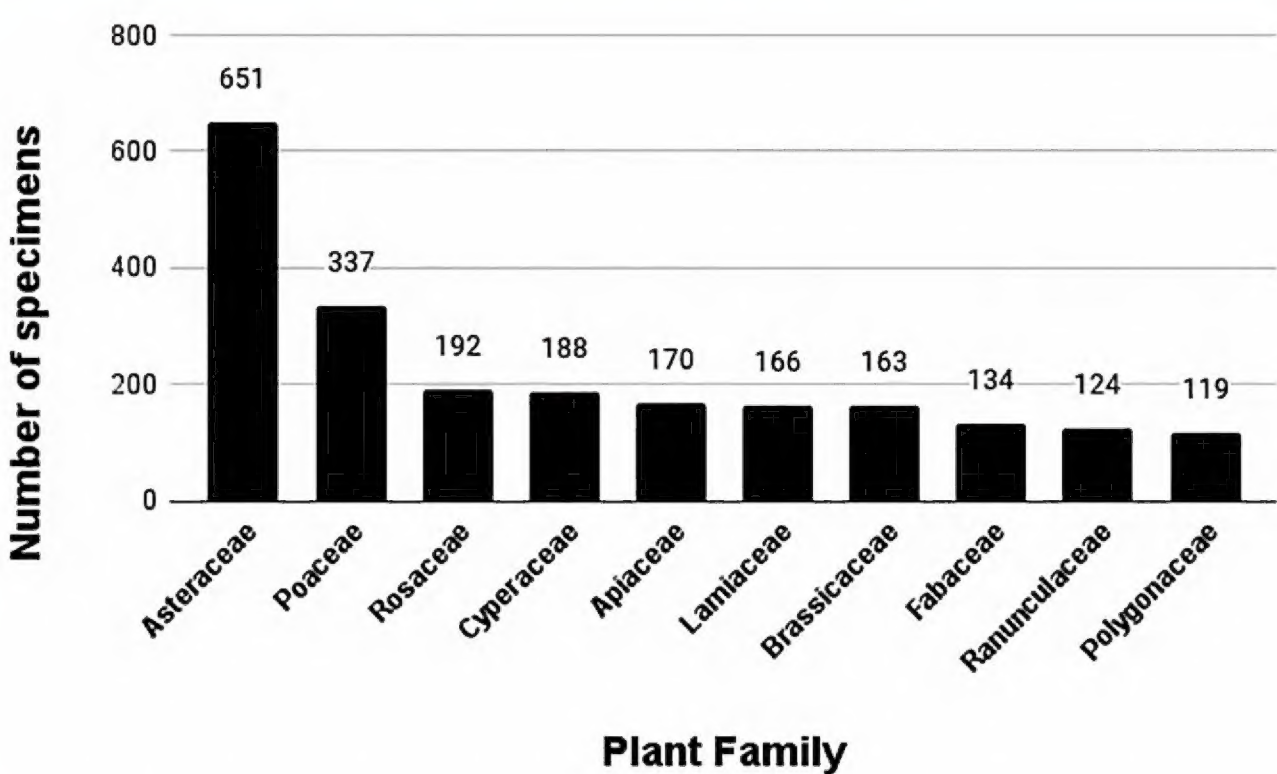


FIGURE 2. The 10 largest plant families represented in the Manchester University collection and the number of specimens in each. Taxonomy follows that of Voss and Reznicek (2012).

Dunes region collected in the 1940s. Numerous species growing in this area are listed by the Indiana DNR as rare, threatened, or endangered because of the unique habitat and its loss to urbanization. The collections at MU represent known populations that, mostly, have some sort of protection. However, more interestingly, the collection hosts an array of wetland and bog plants from Wabash County that were collected in the late 1800s. Many of these specimens, such as *Sarracenia purpurea* L., have not been observed in Wabash County since the 1800s. These specimens likely represent some of the last collections from wetland habitats that were drained and converted to farmland as the area developed into a hub of modern agricultural practices. Unfortunately, precise locations are not listed on the labels, but the habitat is likely gone (David J. Hicks, personal communication).

Specimens have been added in waves throughout the lifetime of the MU collection. These labs reflect particularly active collectors (see Important Collectors, below). The oldest specimen in the collection is a specimen collected by A.B. Ulrey, dated April 4, 1890. Most of Ulrey’s 278 specimens in the herbarium were collected in 1890, and he made all the collections from the five-year period 1890–1895 (Figure 3). There are no collections made between 1895 and 1925. Only a few collections were made between 1925 and 1940 (likely a decline from the depression and WWII) but 629 specimens were collected in 1945–1949. Collection data did not increase until 2005 when 826 specimens were collected. Starting at this point and until 2019, most of the specimens in the herbarium were collected by David J. Hicks. The five-year period that saw the most collection was 2015–2019 with 1,045 specimens collected in that five-year time frame.

59.7% of the collections in the herbarium (2,442 specimens) were collected in

TABLE 1. Specimens of endangered, threatened, and rare plant species of Indiana held in the Manchester University herbarium. Taxonomy is based on the Indiana Department of Natural Resources list (DNR 2021). Only specimens labeled from and growing naturally in Indiana are included. State Ranks: SE = state endangered, ST = state threatened, WL = watch list. GRANK follows the convention of NatureServe (2021).

Species	State Rank/ GRANK	County	Date	Collector
<i>Ammophila breviligulata</i>	WL/G5	Porter	July 27, 1946	O.W. Neher
<i>Anaphalis margaritacea</i>	WL/G5	Kosciusko	October 1, 1988	Jacki Faris
		Miami	September 29, 1957	A. Wildermuth
		Wabash	August 12, 1890	A.B. Ulrey
		Wabash	September 27, 2009	David J. Hicks
		Wabash	September 23, 1947	Raymond Hartsough
<i>Arctostaphylos uva-ursi</i>	ST/G5	Porter	July 27, 1946	O.W. Neher
<i>Cakile edentula</i> var. <i>lacustris</i>	WL/G5T3T5	Porter	July 27, 1946	O.W. Neher
<i>Carex cephaloidea</i>	ST/G5	Steuben	July 6, 2018	David J. Hicks
<i>Carex leptalea</i>	WL/G5	Kosciusko	June 15, 2016	David J. Hicks
		Miami	May 18, 2015	David J. Hicks
		Steuben	May 22, 2018	David J. Hicks
<i>Carex trichocarpa</i>	WL/G4	Miami	May 18, 2015	David J. Hicks
<i>Castanea dentata</i>	SE/G4	Wabash	1890	A.B. Ulrey
<i>Comptonia peregrina</i>	WL/G5	Porter	July 27, 1946	O.W. Neher
<i>Cypripedium acaule</i>	SE/G5	Kosciusko	1935	O.W. Neher
<i>Cypripedium candidum</i>	ST/G4	Wabash	June 24, 1890	A.B. Ulrey
<i>Cypripedium reginae</i>	ST/G4G5	Wabash	June 14, 1956	P.A. Orpurt
<i>Dactylorhiza viridis</i>	SE/G5	Wabash	May 13, 2013	David J. Hicks
<i>Drosera rotundifolia</i>	WL/G5	Elkhart	August 30, 1950	O.W. Neher
<i>Euphorbia polygonifolia</i>	ST/G5?	Porter	July 27, 1946	O.W. Neher
<i>Filipendula rubra</i>	WL/G4G5	Wabash	August 4, 1890	A.B. Ulrey
		Wabash	August 5, 1947	O.W. Neher
<i>Hudsonia tomentosa</i>	ST/G5	Porter	July 27, 1946	O.W. Neher
<i>Hydrastis canadensis</i>	WL/G3G4	Wabash	July 26, 2009	David J. Hicks
<i>Hypericum adpressum</i>	SE/G3	Jasper	July 14, 1994	David J. Hicks
<i>Lathyrus japonicus</i>	SE/G5	Porter	July 27, 1946	O.W. Neher
<i>Liparis loeselii</i>	WL/G5	Wabash	June 24, 2005	David J. Hicks
		Kosciusko	August 26, 2016	David J. Hicks
<i>Lycopodium clavatum</i>	WL/G5	Porter	May 18, 1961	M. Miller
<i>Myosotis laxa</i>	ST/G5	Porter	July 27, 1946	O.W. Neher
<i>Panax quinquefolius</i>	WL/G3G4	Wabash	August 25, 2008	David J. Hicks
		Wabash	August 7, 2007	David J. Hicks
<i>Panax trifolius</i>	WL/G5	Wabash	1890	A.B. Ulrey
<i>Pogonia ophioglossoides</i>	ST/G5	Wabash	23 June 1890	A.B. Ulrey
<i>Rhus aromatica</i> var. <i>Arenaria</i>	ST/G5T3Q	Porter	July 27, 1946	O.W. Neher
<i>Salix serissima</i>	ST/G5	Wabash	June 3, 1956	P.A. Orpurt
<i>Sarracenia purpurea</i>	ST/G5	Porter	July 27, 1946	O.W. Neher
		Wabash	1890	A.B. Ulrey
<i>Selaginella apoda</i>	WL/G5	Wabash	April 24, 1986	P.A. Orpurt
<i>Triantha glutinosa</i>	ST/G5	Steuben	July 18, 2018	David J. Hicks
<i>Trillium cernuum</i> var. <i>macranthum</i>	SE/G5T4	Whitley	May 8, 1956	R.L. McAdams
<i>Vaccinium macrocarpon</i>	ST/G5	Elkhart	August 30, 1950	O.W. Neher
		Wabash	June 23, 1890	A.B. Ulrey
<i>Valerianella chenopodiifolia</i>	WL/G4	Wabash	April 18, 1891	A.B. Ulrey
		Wabash	May 19, 1956	P.A. Orpurt
		Wabash	June 3, 1956	P.A. Orpurt
<i>Veratrum woodii</i>	WL/G5	Wabash	July 27, 2006	David J. Hicks

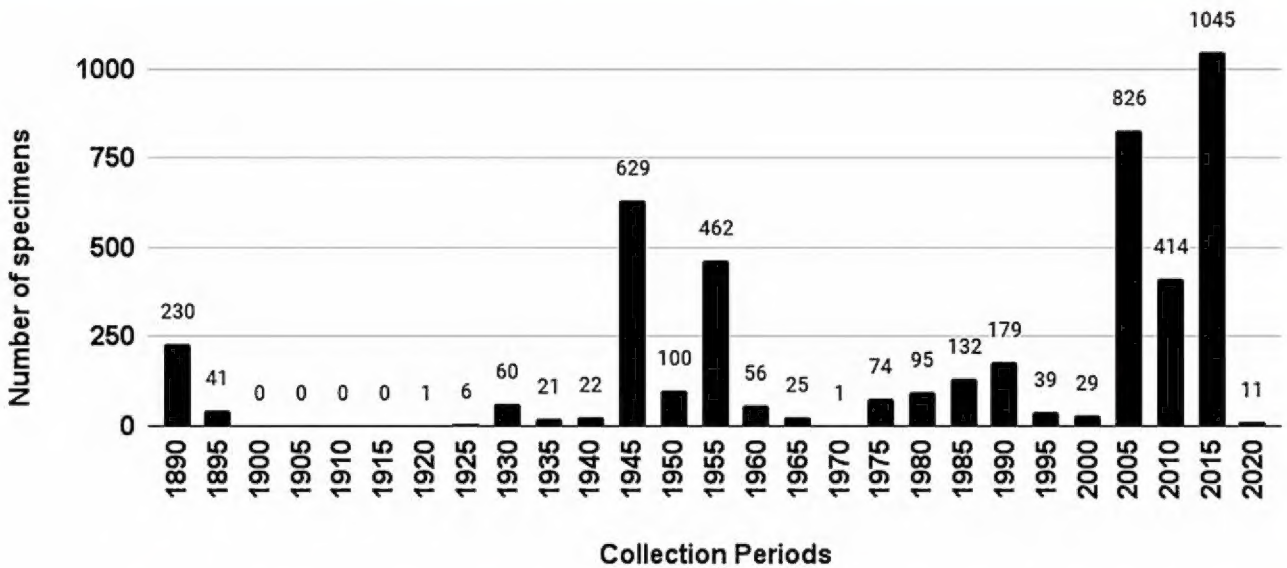


FIGURE 3. The number of plant collections deposited in the Manchester University herbarium in each five-year period beginning from the original collections in 1890 through July 2020. Collections begin on January 1 of the starting year and end on December 31 of the ending year (except July in the case of 2020).

Wabash county, where MU is located. This was followed by the nearby counties of Miami (12.7%), and Steuben (6.3%) (Figure 4). Specimens from Indiana account for 90.7% of the total collections in the herbarium; the remaining specimens are from 22 other states in the United States, except for one specimen each from Chile and Japan.

IMPORTANT COLLECTORS

The most prolific collector of specimens in Manchester’s plant collection is David J. Hicks, who was a professor at MU from 1986 until 2019, where he taught courses in genetics, ecology, and botany. Dr. Hicks contributed 2,063 specimens to the herbarium, which constitutes 44.3% of the total (Figure 5). Hicks graduated from Colgate University in 1974 with a bachelor’s degree in biology, and he earned his master’s degree and Ph.D. from Cornell University in 1978 and 1982, respectively, with a focus on plant ecology (Manchester University 2020). Many of the collections from Hicks came from floristic surveys of local land easements, particularly properties managed by the local ACRES land trust, as well as from student floristic studies under his supervision.

Oscar W. Neher (O.W. Neher), a professor at Manchester from 1932 until 1954, taught classes in botany and microbiology (Eberly 2005). Neher contributed 667 specimens to the herbarium, which constitutes 14.3% of the total (Figure 5). Neher earned his bachelor’s degree from Iowa State College of Agriculture and Mechanical Arts in 1921 and his master’s degree from the University of Chicago in 1930 (Eberly 2005). Initially, Neher taught biology at Mount Morris College until its merger with Manchester, when Neher became an associate professor of biology at Manchester College and began taking students on trips to

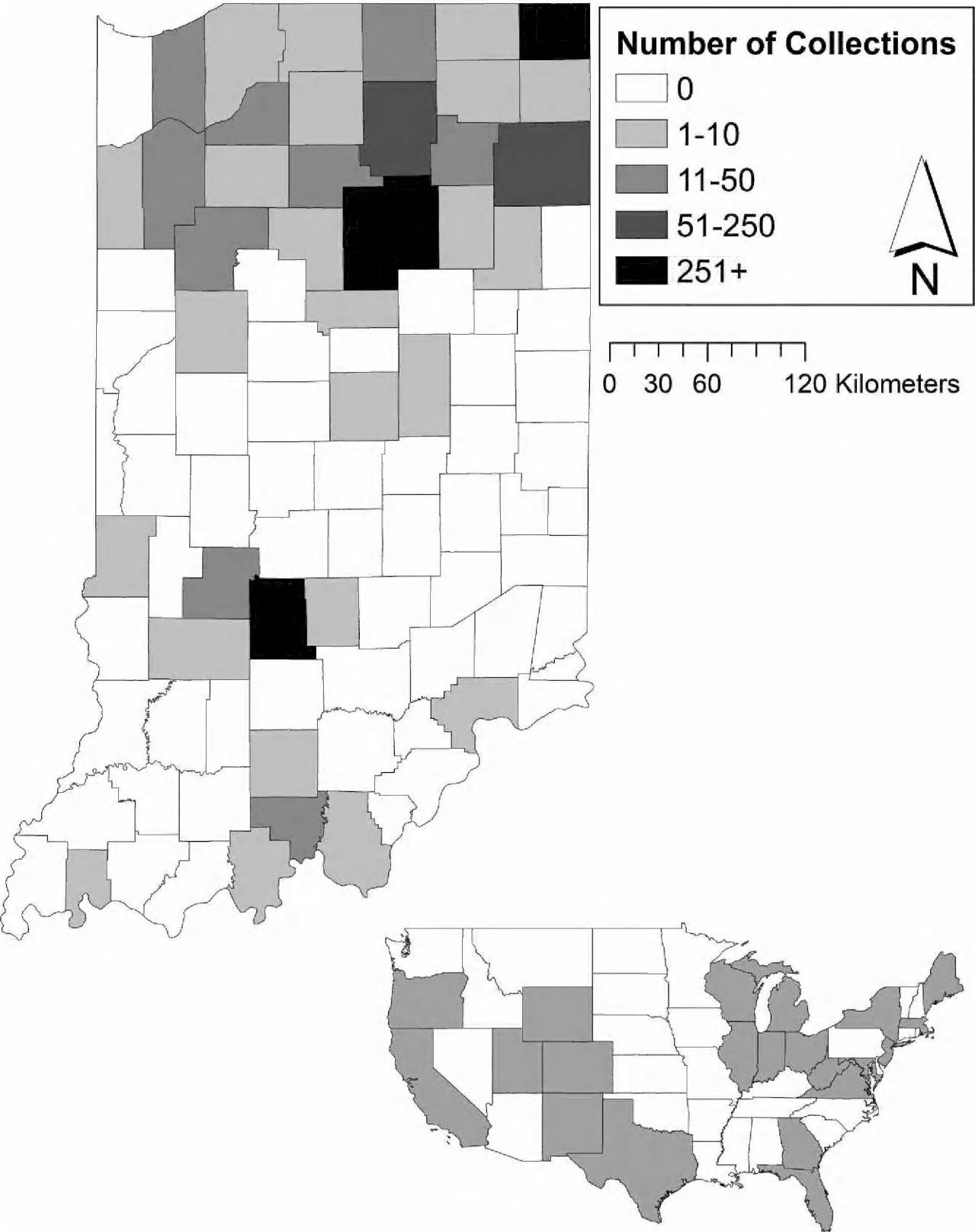


FIGURE 4. Collecting localities of specimens held in the Manchester University herbarium by state in the continental United States and by county in Indiana. Highlighted states are those represented by specimens in the collection. Counties in Indiana are color shaded by the number of collections from that particular county. The collections from Chile and Japan are not shown here.

neighboring states to observe plants (Eberly 2005). Many of Neher’s collections likely came from these trips as well as from his personal collection started at Mount Morris College. Neher was also one of two professors who took it upon themselves to plant a variety of rare and exotic trees on campus. Many of these

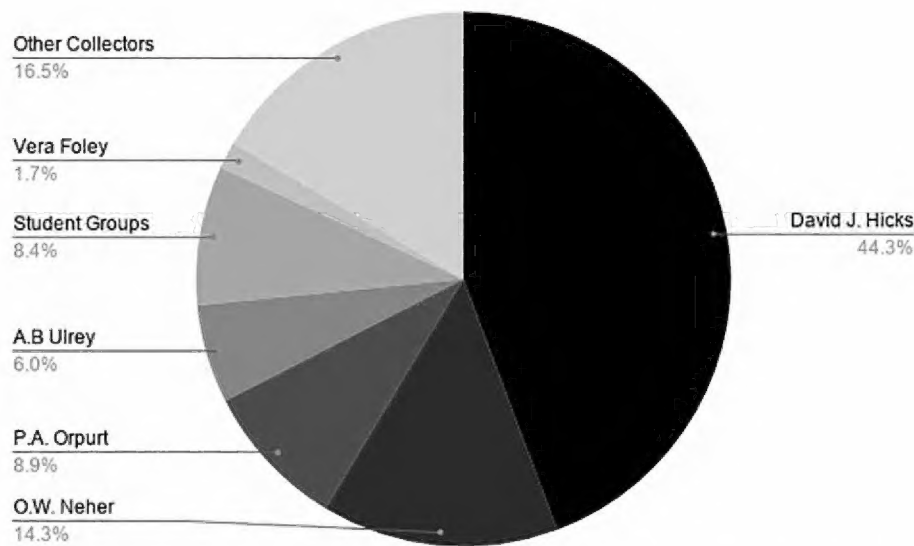


FIGURE 5. Major collectors of the Manchester University plant collection and the percentage of the collection accredited to each of them.

plantings are included in the herbarium in addition to many naturally occurring specimens.

Philip A. Orpurt taught at MU from 1954 to 1989. He contributed 413 specimens to the herbarium, or 8.9% of the total (Figure 5). After earning his bachelor’s degree in biology from Manchester College in 1948, Orpurt attended the University of Wisconsin, where he received his master’s degree in 1950 and his Ph.D. in 1954 with a specialization in botany, mycology, and plant ecology (Eberly 2005). He returned to Manchester College in 1954 to replace O.W. Neher and took up teaching courses in biology, historical geology, botany, and genetics (Eberly 2005). Many of Orpurt’s collections represent his time in Wisconsin, and a few are collections of diseased plants, a specialty of his. Orpurt also made fungal collections that are housed at MU; these are not, however, currently inventoried.

The final major contributor to the plant collection is A.B. Ulrey, who contributed 278 specimens to the herbarium, or 6.0% of the total (Figure 5). Despite not receiving his bachelor’s and master’s degrees from Indiana University until 1892 and 1894, respectively, Ulrey was listed as the only science professor at Manchester College in the spring of 1891 (Eberly 2005). School records show Ulrey teaching courses in zoology, botany, geology, and chemistry, along with many practical labs in 1896. Ulrey set the model for much of the development of the sciences at MU by emphasizing practical hands-on instruction, which included many student contributions to MU’s plant collection.

CONTRIBUTIONS OF WOMEN TO BOTANY
AT MANCHESTER UNIVERSITY

Of the 4,658 specimens in Manchester University’s plant collection, 200 were collected by women, making up 4.3% of the total. The two most prolific female



FIGURE 6. Professor Sadie Stutsman Wampler, seated on the right, and her painting class (ca. 1910). She frequently used specimens held at Manchester as models for her classes and painted them in realistic color. Photo provided by the Manchester University Archives and Peace Studies Church of the Brethren Collection, North Manchester, Indiana.

collectors, Vera Foley, with 77 collections, and Joyce Rupel, with 33 collections, together contributed 110 plants, or 55% of the contributions made by women (Figure 5). Unfortunately, not much is known about these two women other than their contributions to the MU collections. However, we do know that Rupel collected all but one of Manchester's specimens from southern California, and that Foley collected specimens from northeastern Indiana. We also believe that Foley and Rupel could have been students at Manchester, since most of their collections were made in a single year. Another notable collector is Barbara J. Ehrhardt, who is the only professor among the female collectors, having taught at Manchester from 1989 until 2004. Ehrhardt graduated from Manchester College in 1989 with a bachelor's degree in environmental studies and then again with a master's degree in 1994. Ehrhardt started her teaching at Manchester as a teaching assistant in field biology during her senior year in 1989. This allowed Ehrhardt to join the faculty later as Professor of Environmental Education. In 1991, Ehrhardt became Director of the Koinonia Environmental and Retreat Center, a nature preserve owned by MU and used by its environmental studies students (Eberly 2005).

Women have also done more than just collect specimens for MU's plant col-

lection. In the earlier years of the collection, art professor Sadie Stutsman Wampler and her art students painted watercolors of specimens and collected them into books (Figure 6). Had these books remained in the plant collection, they would have served to preserve aspects of plants that would fade over time, such as color and patterns on leaves, branches, or flowers. However, they are currently held in the Manchester University archives on the North Manchester campus.

FUTURE PLANS FOR THE PLANT COLLECTION AT MANCHESTER UNIVERSITY

Our goal for this project was to understand what the plant collection at Manchester University has to offer and to make it available for use by researchers outside of the university. In the future, we hope that researchers will use the plant collection as a resource for projects throughout northeastern Indiana as well as add to the overall knowledge of the Indiana flora. In addition, we hope to eventually submit an application for the herbarium to be added to Index Herbariorum in order to further these goals.

ACKNOWLEDGMENTS

Funding for this project was provided by the Niswander Endowment for the Niswander Biology Department and an Office of Academic Affairs Student-Faculty grant. The Plant Systematics class (Fall 2019) at Manchester University assisted in the cataloging of specimens. We also thank the archives at Manchester University for providing photos and historical context.

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AN OLD GROWTH OAK FOREST AT LEONARD WILDLIFE PRESERVE IN BERRIEN COUNTY, MICHIGAN

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ABSTRACT

In the past, much of the eastern United States was covered by old growth oak and oak–hickory forests in which white oak was a dominant species. Periodic low severity fires were thought to maintain these forests by eliminating competition from shade tolerant species and increasing light transmission to the forest floor. After European settlement, much of these forests were logged, and fire was suppressed in those that remained, causing a decline in white oaks. A 15-ha forest at Leonard Wildlife Preserve near Lakeside, Michigan, was found to have numerous very large diameter white and red oaks. The tree species composition and demography were described from samples taken at the preserve in 2020. In addition, canopy cover and light measurements were taken to determine if sufficient light existed at the forest floor to support the survival of oak seedlings and their recruitment. The forest canopy was found to be dominated by white oak and red oak, some of which exceeded 150 years of age, with a subcanopy of sugar and red maple and American beech. Size class frequency distributions showed that red and white oaks had gaps in smaller size classes indicative of populations that may be in decline. The same was not true for the maples and beech, which seemed poised to replace the aging oaks. Light intensity was found to be below that conducive for oak survival.

KEYWORDS: Oak–hickory forest, tree species composition, demography, Michigan

INTRODUCTION

Old growth forests have been defined in many ways. Some have been defined in process terms as “stands that develop in the absence of allogenic processes” (Oliver and Larson 1996), others in terms of their composition (Leak 1973), structure (Franklin et al. 1981), demography (Leak 1973), age of dominant trees (Frelich 1995), and presence of standing dead and fallen trees (Franklin et al. 1981). Most old growth forests in the United States are coniferous forests in western states, but others are found among hardwood forests of the eastern states. In the central hardwood region, old growth stands exist, but they are scattered from Minnesota south to Arkansas and east to Tennessee and north to Ohio and Michigan (Fralish 2003) and consist of less than 100,000 ha (Parker 1989). In Michigan, only 22 stands (474 ha) have been recorded based on the definition of old growth as stands with trees ≥ 150 years old in multi-layered canopies containing standing dead and downed trees and with little or no human disturbance during the past 80–100 years (Parker 1989).

According to interpretations of the General Land Office Public Land Surveys, the uplands of southwestern Michigan were composed of a variety of old growth hardwood forests (e.g., oak, oak–hickory, oak–pine, and beech–sugar maple)

(Brewer et al. 1984; Comer and Albert 1997), in which beech–maple forests are on more mesic sites than the oak and oak–hickory forests (Dickmann and Leefers 2003). More specifically, the Comer and Albert (1997) map of the vegetation of Berrien County shows that much of the western half of the county was beech–maple forest, but that oak and oak–hickory forests occupy narrow bands adjacent to Lake Michigan. In his 1829 survey notes from T7S, R20W, the township in which the Leonard Wildlife Preserve is located, Lucius Lyon, Deputy Surveyor, wrote “. . . land the same as the last half mile except near the Lake where Beech and Ash mingle with the Oak” (Lyon 1829). He also lists the general timber composition as beech, maple, and oak along Lake Michigan. Since statehood, most of these forests have been logged and abandoned or converted to agriculture or homesites. In 1966 there were 2.405 million acres (973,269 ha) of oak forests in Michigan, including 1.016 million acres (411,161 ha) in southern Lower Michigan (Arend and Scholz 1969). In 2017, oak forest acreage for the entire state had increased to ca. 3.1 million acres (ca. 1.25 million ha) (Pugh 2018). Based on current species composition, oaks are among the dominant tree species in two of the three predominant forest types in southwestern Lower Michigan (dry southern forest, and dry-mesic southern forest) and are present in lower numbers in the third (mesic southern forest) (Cohen et al. 2015). Oaks are also dominants in oak barrens, oak–pine barrens, oak openings, lakeplain openings, and bur oak openings (Cohen et al. 2015).

A decline in oak forests and especially in white oak populations across the entire eastern half of the United States has been noted and attributed to the suppression of fire (Abrams 2006). Periodic low severity fires are reported to eliminate competing understory species and expose the forest floor to increased light which is required by white oak for survival and growth (Dey 2014). Although Abrams (2006) did not include southern Michigan in support of his thesis that white oaks were declining, several reports describing small forests in southern Michigan have indicated a potential decline in oaks due to poor reproduction (Dodge and Harman 1985) and low recruitment (Larch and Sakai 1985). This decline kindled an interest when I walked through a small forest in Berrien County in 2018. What caught my attention were numerous large white oak and red oak trees, many exceeding 60 cm in diameter, and some as large as 100 cm. This led to the following objectives: 1) to describe the tree composition of this forest, 2) to determine the age of some of the larger trees, 3) to determine the fate of the dominant tree species and the forest in general, 4) to determine if oaks are experiencing decline, and, if so, 5) to determine if low light intensity at the forest floor might be a contributing factor.

METHODS AND MATERIALS

Site Description

The 44 hectares of Leonard Wildlife Preserve are located south and west of the junction of Lakeside Road and Warren Woods Road in Berrien County in southwestern Michigan about 1.6 km east of Lake Michigan and about 3.3 km due west of Warren Woods State Park. The preserve is owned by Chikaming Open Lands, a nonprofit land conservancy organization in Sawyer, Michigan. The 15-hectare wooded portion described herein is located at the north end of the preserve (41°50'07"N, 86°40'17"W). The topography of the forest, which sits atop the Lake Border Moraine, a low morainial

ridge flanked by lowland plains, is flat with a gentle slope to the south. Within the forest are several wet areas and a shallow creek in a deep ravine that follows the gentle slope from north to south. The soils, mapped as Blount Loam (Web Soil Survey 2019), are somewhat poorly drained and have a high water table. A preliminary examination of the forest revealed the presence of large white oak (*Quercus alba* L.) and red oak (*Quercus rubra* L.) trees and smaller sugar maple (*Acer saccharum* Marshall), red maple (*Acer rubrum* L.), and American beech (*Fagus grandifolia* Ehrh.) trees. Among the understory are shrubs of *Lindera benzoin* (L.) Blume, *Viburnum acerifolium* L., and *Toxicodendron radicans* (L.) Kuntze and vines of *Smilax rotundifolia* L. and *Parthenocissus quinquefolia* (L.) Planch. Common herbaceous species include *Arisaema triphyllum* (L.) Schott, *Geranium maculatum* L. and several species of sedges.

Sampling Procedure

In the summer of 2020, I randomly located 116 sampling points no less than 20 m apart along 26 transects that were 30 m apart and extended in a north to south direction. At each point, I used a randomly generated set of ones and twos with the number one indicating that the point was to be sampled and two that the point was to be skipped. All sampling points were at least 30 m from forest edges and property boundaries. At each sampling point, I counted all individuals ≤ 30 cm tall of each tree species in one 2-m² circular plot whose center coincided with the center of a 100-m² circular plot whose center was the sampling point. All trees > 30 cm tall were counted in the larger plot. For each tree > 2.5 cm dbh, I measured the circumference at 1.4 m and converted it to dbh (diameter at breast height). The frequency of occurrence of each species in each sampling plot, the density of each species, and the mean dbh for each species were each converted to a proportion of the total for that measurement. The proportions were then summed for each species over all sampling points to yield an Importance Value. Densities of trees > 30 cm tall were separated by diameters into size class bins that were 10 cm wide and plotted as frequency distributions to assess patterns of reproduction and recruitment.

To determine if low light intensity might be a factor in the survival and growth of oak populations at Leonard Wildlife Preserve, I measured irradiance (watts per square meter) at 15 cm above ground at the forest floor in 62 of the 116 sampling point centers using a light meter described by Tatina (1998). Each of these sampling points was chosen from a randomly generated sequence of 62 numbers between 1 and 116. Because simultaneous measurements of light in the forest and in the open could not be made, I used irradiance measurements from an open field adjacent to the forest to determine how much light reached the top of the canopy. The average of three measurements of a cloudless sky, a cloudy bright sky, and an overcast sky were taken at 1200 hrs, 1400 hrs, and 1600 hrs. Then, to determine the percentage of light reaching the forest floor, I selected that reading which best corresponded to the sky when a forest measurement was taken. Percentage transmittance was calculated as (forest floor irradiance / open sky irradiance) \times 100.

To further assess the effect of the canopy in attenuating sunlight, I measured canopy density with a Model A spherical densiometer (Forest Densiometers, Bartlesville, OK 74006) described by Lemon (1956). At the same 62 sampling point centers where irradiance was measured, I recorded four canopy density readings, one in each cardinal direction. The four readings were averaged, multiplied by 1.04, and then subtracted from 100% to yield the percentage canopy cover. I then calculated the average over all canopy cover percentages.

Tree cores were taken from *Quercus alba* and *Q. rubra* at breast height in late August and mid-September, and growth rings were counted to estimate tree ages. No correction was made for growth rings below breast height.

Nomenclature follows Voss and Reznicek (2012). Voucher specimens of all tree species were deposited at MICH.

RESULTS

Nineteen tree species were included in 116 sample plots (Table 1). All of these species except *Carpinus caroliniana*, *Ostrya virginiana*, *Cornus florida*, *Hamamelis virginiana*, *Asimina triloba*, and *Crataegus* sp. have the potential to

TABLE 1. Measurements and calculated values of tree species at the oak forest at Leonard Wildlife Preserve, Berrien County, Michigan, in 2020, based on trees >2.54 cm in diameter at breast height (dbh).

Species	Frequency	Density (trees/ha)	Mean dbh (cm ± sd)	Basal Area (m²/ha)	Relative Frequency	Relative Density	Relative Dominance	Importance Value
<i>Quercus alba</i> L.	0.500	87.07	52.18 ± 13.64	14.325	0.127	0.100	0.437	0.664
<i>Quercus rubra</i> L.	0.362	49.14	62.67 ± 28.50	13.138	0.092	0.056	0.400	0.549
<i>Acer saccharum</i> Marshall	0.689	178.45	10.85 ± 7.53	1.760	0.178	0.204	0.054	0.436
<i>Acer rubrum</i> L.	0.534	178.45	8.87± 6.96	1.281	0.136	0.204	0.039	0.380
<i>Fagus grandifolia</i> Ehrh.	0.414	88.97	9.09 ± 7.70	0.709	0.105	0.102	0.022	0.229
<i>Carpinus caroliniana</i> Walter	0.284	73.28	4.24 ± 1.40	0.083	0.073	0.084	0.003	0.159
<i>Ulmus americana</i> L.	0.233	72.41	6.75 ± 4.17	0.257	0.059	0.083	0.008	0.150
<i>Ostrya virginiana</i> (Mill.) K. Koch	0.250	37.07	5.52 ± 1.92	0.072	0.064	0.042	0.002	0.108
<i>Carya ovata</i> (Mill.) K. Koch	0.164	25.86	17.63 ± 15.02	0.774	0.042	0.030	0.024	0.095
<i>Tilia americana</i> L.	0.147	25.86	11.94 ± 9.11	0.326	0.037	0.030	0.010	0.077
<i>Hamamelis virginiana</i> L.	0.103	26.72	3.88 ± 0.96	0.024	0.026	0.031	0.001	0.058
<i>Prunus serotina</i> Ehrh.	0.121	15.52	5.01± 2.14	0.026	0.031	0.018	0.001	0.049
<i>Fraxinus pennsylvanica</i> L.	0.060	5.17	6.05 ± 3.77	0.014	0.015	0.006	0.000	0.022
<i>Cornus florida</i> L.	0.026	3.45	6.84 ± 1.41	0.009	0.007	0.004	0.000	0.011
<i>Asimina triloba</i> (L.) Dunal	0.009	1.72	4.93 ± 2.93	0.003	0.002	0.002	0.000	0.004
<i>Amelanchier laevis</i> Wiegand	0.009	1.72	2.71 ± 0.23	0.001	0.002	0.002	0.000	0.004
<i>Nyssa sylvatica</i> Marshall	0.009	0.86	6.05	0.002	0.002	0.001	0.000	0.003
<i>Sassafras albidum</i> (Nutt.) Nees	0.009	0.86	4.77	0.001	0.002	0.001	0.000	0.003
<i>Crataegus</i> sp.	0.009	0.86	3.18	0.000	0.002	0.001	0.000	0.003
TOTALS	3.992	873.28		32.805	1.000	1.000	1.000	3.000

TABLE 2. Density (number per hectare) of tree seedlings (≤ 30 cm tall) and juveniles (> 30 cm tall and ≤ 2.54 cm dbh) at Leonard Wildlife Preserve in 2020.

Species	Seedlings	Juveniles	Voucher
<i>Acer rubrum</i> L.	129.3	30.2	Tatina 2059
<i>Acer saccharum</i> Marshall	258.6	73.3	Tatina 2052
<i>Amelanchier laevis</i> Wiegand	43.1	14.7	Tatina 2057
<i>Asimina triloba</i> (L.) Dunal	0.0	63.8	Tatina 2070
<i>Carpinus caroliniana</i> Walter	732.8	288.8	Tatina 2055
<i>Carya cordiformis</i> (Wang.) K. Koch	0.0	0.9	Tatina 2058
<i>Carya ovata</i> (Mill.) K. Koch	732.8	180.2	Tatina 2056
<i>Cornus florida</i> L.	0.0	8.6	Tatina 2071
<i>Crataegus</i> sp.	0.0	4.3	Tatina 2061
<i>Fagus grandifolia</i> Ehrh.	0.0	82.8	Tatina 2064
<i>Fraxinus pennsylvanica</i> L.	3793.1	343.1	Tatina 2062
<i>Hamamelis virginiana</i> L.	0.0	52.6	Tatina 2072
<i>Liriodendron tulipifera</i> L.	0.0	0.9	Tatina 2073
<i>Ostrya virginiana</i> (Mill.) K. Koch	0.0	25.0	Tatina 2051
<i>Prunus serotina</i> Ehrh.	646.6	64.7	Tatina 2053
<i>Prunus virginiana</i> L.	0.0	8.6	Tatina 2066
<i>Quercus alba</i> L.	172.4	3.4	Tatina 2050
<i>Quercus rubra</i> L.	1250.0	44.8	Tatina 2068
<i>Tilia americana</i> L.	0.0	6.0	Tatina 2065
<i>Ulmus americana</i> L.	43.1	60.3	Tatina 2054
<i>Viburnum lentago</i> L.	0.0	78.4	Tatina 2063
TOTALS	7801.7	1435.3	

become part of the canopy. The most important species were *Quercus alba* and *Q. rubra*. Although these were not of the highest density, they were the largest trees, having average diameters of 52.18 cm (max. 92.95 cm) and 62.67 cm (max. 123.19 cm), respectively. Other commonly encountered tree species included *Acer rubrum*, *A. saccharum*, *Fagus grandifolia*, and *Ulmus americana*. Except for *F. grandifolia*, which was represented by several large diameter trees, few of the others were large trees. Notably present, although at relatively low density, was *Carya ovata*, which is usual for this species in oak–hickory forests (Braun 1950; Curtis 1971).

Understory seedlings and juvenile individuals are light interceptors. Their combined density is shown in Table 2. Of these, *Fraxinus pennsylvanica* is the most abundant. Other forests in the area also have contained high densities of seedling and juvenile *Fraxinus* spp. trees (Tatina 2016, 2010), as have forests elsewhere in the Midwest (Klooster et al. 2014; Aubin et al. 2015; Kashian 2016; Abella et al. 2019). Both *Quercus rubra* and *Q. alba* were found as seedlings and juveniles, but *Q. rubra* is seen to out-reproduce *Q. alba*. The same situation was reported by Curtis (1971) for these two species in Wisconsin forests. For some species, such as *Fagus grandifolia*, there was an absence of seedlings. This is probably due to the absence of a mast crop in the years preceding 2020, a phenomenon that is usual for this species (Tatina 2015). Other notable species include *Carpinus caroliniana*, whose seedling numbers result from root and stump

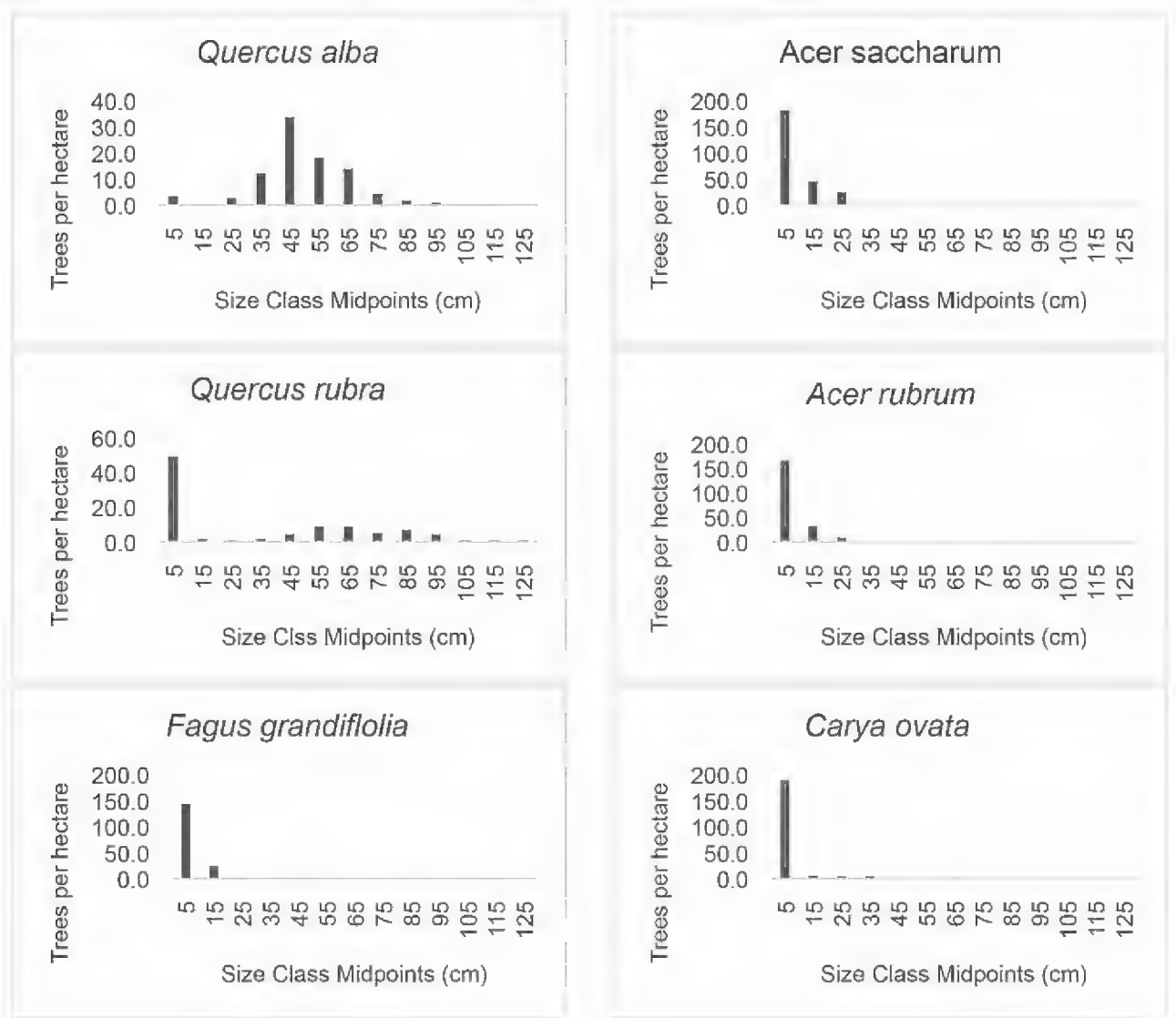


FIGURE 1. Frequency distribution of diameters (cm) of tree species at Leonard Wildlife Preserve in 2020. Bin width is 10 cm. Note that not all vertical axes are the same.

sprouts often associated with clumps of juvenile individuals, and *Carya ovata*, whose density indicates that it is reproducing.

When tree densities are plotted by diameter size classes (Figure 1), *Quercus alba* exhibited very low densities in the 5, 15, and 25 cm size classes, and *Q. rubra* in the 15, 25, and 35 cm size classes, indicating a failure of reproduction and/or recruitment at some time in the past. *Carya ovata* had a relatively high density of juvenile individuals (5 cm), but very low densities in size classes larger than that (Figure 1), indicating that the few larger trees are producing mast crops. At the same time, shade tolerant species such as *Fagus grandifolia*, *Acer saccharum*, and *A. rubrum* have reverse J frequency distributions (Figure 1), consistent with young populations that are reproducing and recruiting individuals into larger size classes.

The largest of the *Quercus alba* trees that were cored had a diameter of 83 cm (mean diameter = 45.7 cm ± 18.8 (sd.), n = 110) and was at least 144 years old based on ring counts but was probably older since the core was taken at 1.4 m above ground. Three trees exceeded 83 cm (89, 90, and 93 cm). The largest *Q. rubra* tree that was cored had a diameter of 87 cm (mean diameter = 54.1 ± 20.79

(sd), $n = 8$) and a minimum age of 116 years. Thirty-three trees were larger than this, the largest of which was 123 cm in diameter.

Mean canopy coverage for 62 densiometer measurements was $81\% \pm 6.4$ (sd). The mean light transmittance near the forest floor was $18.54\% \pm 0.04$ (sd). Several studies have shown that *Q. rubra* seedlings grow poorly in low light intensities (Loach 1967; Phares 1971; Crow 1992) and that seedlings of both *Quercus alba* and *Q. rubra* grow better at light levels that are greater than 15% of full sunlight (Brose and Rebbeck 2017). Specifically, they found that *Q. rubra* can grow reasonably well in 15% to 40% sunlight, but that *Q. alba* requires 40% or more. Bourdeau (1954) reported that when planted in shade, *Q. rubra* grew approximately 60% taller than *Q. alba* over one growing season.

DISCUSSION

The forest at Leonard Wildlife Preserve is dominated by oaks and may be classified as an oak–hickory forest. The two oak species contained individuals that were very large, some over 90 cm in diameter. Based on size, some of these large trees may exceed 150 years old. This forest may be considered old growth (Parker 1989), even though it is more probably a second growth forest developing after having been logged in the 1800s. The low Importance Values for early successional species (*Prunus serotina*, *Sassafras albidum*, and *Crataegus* sp.) (Table 1) further support a long history of absence of major human disturbance. Although *Quercus alba* and *Q. rubra* are long lived, some exceeding 500–600 years for *Q. alba* and 300 years for *Q. rubra* (Barnes and Wagner 2004), the absence of individuals in one or more size classes may indicate a recruitment and/or reproductive failure. These failures are probably due to shading by the closed canopy, shading by seedling and juvenile plants, and shrubs like *Lindera benzoin*, *Viburnum acerifolium*, *Rosa multiflora* Murray, and others (personal observation by the author), which together produce a light intensity environment near the forest floor that is not conducive to the growth and survival of oak seedlings. When larger oak trees die, they may not be replaced. Meanwhile, some of the advance regeneration of *Fagus grandifolia*, *Acer saccharum*, and *A. rubrum* may replace them. These are gap replacing species (Abrams 1998; Poulson and Platt 1996) which remain in the shaded understory until a canopy tree topples, at which time they accelerate upward growth. Like most oak–hickory forests in the central states (Sander 1977) and in Michigan (Dodge and Harman 1985; Larch and Sakai 1985; Hammitt and Barnes 1989), the density of canopy-size hickory trees is very low, perhaps because this species grows more slowly than oaks (Graney 1990).

Others who have studied oak–hickory forests in Michigan have predicted the decline of oaks (Brewer et al. 1973; Larch and Sakai 1985). Prevention of low intensity ground fires in oak–hickory forests has been suggested as the prime cause for the decline of this forest type (Lorimer 1989; Adams and Rieske 2001; Abrams 2006; Nowacki and Abrams 2008). In 1911, the U.S. Congress passed the Weeks Act, which directed federal foresters to provide fire protection for forests; state

foresters soon followed this directive (Pyne 1997). Thus, it seems reasonable that fire prevention may have started subsequent to that date, promoting the closure of the forest canopy. This would allow faster growing seedlings of mesophytic species to eventually overtop the slower growing oaks, which would lose the competition for light (Lorimer et al. 1994), a resource they require in order to survive. To encourage the replacement of the overstory oaks would require the removal of the understory, an activity accomplished in the past by periodic ground fires. These fires would have killed susceptible species like beech, the maples, ash, etc. and fostered oaks and hickories. Given that the forest at Leonard Wildlife Preserve is sandwiched between residential properties, burning may be considered a dangerous nuisance, and fire may no longer be an option for the forest. Instead, mechanical removal of understory and an occasional treefall, either by cutting or by blow-down, would increase light intensity to the forest floor.

Interestingly, a forest 2.5 km to the northeast of Leonard Wildlife Preserve had a similar species composition of oaks, maples, beech, and hickory; however, it differed in that both *Quercus alba* and *Q. rubra* were reproducing and recruiting into larger size classes (Tatina 2016). The several larger *Q. alba* and *Q. rubra* trees in this forest that were cored indicated an age in 2012 of 113 to 116 years ($n = 3$). The same species from Leonard Wildlife Preserve are, on average, larger (for *Q. alba* mean dbh = 52.18 cm compared to 29.18 cm, and for *Q. rubra* 62.67 cm compared to 29.95 cm, unpublished data available from author) and older. Perhaps the oak forest at the Leonard Wildlife Preserve has been spared from fire for a longer period, creating conditions that cause the gaps in the size classes for the oaks.

Whatever management strategy is planned to maintain an oak–hickory forest, all stages in the life cycle of the oaks and subdominant species should be considered (Arthur et al. 2012). I would extend this to seedlings and saplings of abundant understory species. At Leonard Wildlife Preserve, the most abundant arborescent understory species is *Fraxinus pennsylvanica*. Currently it contributes to the shading of oak seedlings. However, since there were no individuals within the forest sufficiently mature to reproduce (i.e., ≥ 20 cm dbh) (Aubin et al. 2015), the current seedlings probably have sprouted from seeds in the seed bank. Once that bank is exhausted, usually within a few years (Klooster et al. 2014), there will be no reproduction, and those that survive to become ≥ 4 cm dbh may be attacked by emerald ash borer (Abella et al. 2019). Thus, at least plants of this abundant species will not be contributing to the shading.

The oak-hickory forest at Leonard Wildlife Preserve, like the presettlement ones that were mapped nearby along the coast of Lake Michigan (Comer and Albert 1997), seem to represent an island in the midst of an area considered to have been a beech-sugar maple forest prior to settlement by Europeans. What caused the development of these small populations? Were these morainal sites drier and thus more favorable for colonization by oaks over beech and maple? Once established, were these forests maintained by periodic fire or, after settlement, by grazing?

ACKNOWLEDGMENTS

I am grateful to Nancy Baird and Brad Slaughter for critical reviews of an earlier version of this manuscript. Thanks also to Josh Cohen for helpful comments about old growth forests in Michigan,

to Pat Fisher for explaining the landforms of southwestern Michigan, and to J. Dan Skean, Jr., and an anonymous reviewer, and the editor for their attention to detail and helpful suggestions that increased the clarity of my writing.

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BENTHIC DIATOM (BACILLARIOPHYTA) FLORA OF TORCH LAKE, MICHIGAN, AN OLIGOTROPHIC, ALKALINE ECOSYSTEM WITH EVIDENT BENTHIC DIATOM PRODUCTION, WITH A CONSIDERATION OF SOME NEW AND INTERESTING SPECIES

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ABSTRACT

A survey of the diatom flora of Torch Lake in northern lower Michigan was conducted. Torch Lake is oligotrophic and has been experiencing increased growth of littoral zone algae. Diatoms were collected and analyzed as part of a larger study in 2014. 176 diatom taxa were recorded. We present detailed light and scanning electron microscopy observations on 11 taxa, six of which are species new to science, three of which are new reports from the United States, and one of which is given a new name. The new species are *Fragilaria pettyorum*, *Gomphonema melfii*, *Cymbella torchiana*, *Epithemia antrimiana*, *Nitzschia michiganiana*, and *Cymatopleura narwoldorum*. *Encyonema evergladianum* is transferred to the genus *Encyonopsis* resulting in the new combination *Encyonopsis evergladianum*. The diatom flora of Torch Lake is similar to that of large alkaline, oligotrophic lakes in Europe, and has several species in common.

Keywords: diatoms, Bacillariophyta, Torch Lake, taxonomy, ultrastructure, new species, new distribution records

INTRODUCTION

Oligotrophic lakes, those lakes that are relatively pristine due to their younger age or lack of nutrient inputs (e.g. Wetzel 2001), have not had the attention that many other types of freshwater ecosystems have had, especially with respect to diatom floristics (Kociolek and Stoermer 2009). Perhaps the most extensive

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study of oligotrophic lakes is Lange-Bertalot and Metzeltin (1996), which studied three oligotrophic lakes in northern Europe and found nearly 800 taxa of diatoms; note that the entire diatom flora of Europe was estimated to be 1600 taxa (Krammer and Lange-Bertalot 1986; 1988, 1991a, b). Not only were these oligotrophic lakes species-rich, but many of the species present could not be assigned to described species. Lange-Bertalot and Metzeltin (1996) described 55 new species from these lakes and could not assign a name to another 150 taxa; many of these were assumed to be new to science but required additional documentation.

The diatom flora of northern Michigan has had renewed focus since the work of Stoermer and colleagues and Patrick and Reimer (1966, 1975) documented diatoms from the Great Lakes region (e.g., Stoermer and Yang 1971; Stoermer 1978; Stoermer and Kreis 1978; Stoermer and Andresen 1978; Stevenson and Stoermer 1978; Kreis and Stoermer 1979; Kingston et al. 1980 a, b; Stoermer et al. 1981; Kingston et al. 1983; Kociolek and Stoermer 1990, 1991; Edlund and Stoermer 1999; Edlund et al. 2000; Stoermer and Andresen 2006). This work resulted in the description of fewer than 15 new taxa. Graeff et al. (2012) described new species from habitats in the vicinity of the University of Michigan Biological Station, and Anderson et al. (2013) provided a preliminary list and described three new species from Lake of the Clouds in Michigan's Upper Peninsula. Later, Mark et al. (2019) described a new species from the environs of the University of Michigan Biological Station. Reavie and Kireta (2015) also recently documented the near-shore centric, araphid, and eunotioid diatoms from the Great Lakes, but did not describe any new species.

Lakes in the northern portion of the lower peninsula of Michigan are plentiful, and while many of them have seen increases in the number of summer residences around them, potentially bringing increased nutrient inputs into the systems, the deeper lakes may still remain oligotrophic (Michigan Department of Environment, Great Lakes, and Energy 2021) due to the larger volumes of water in deep lakes. Torch Lake, located in Antrim County, near Grand Traverse Bay of Lake Michigan, is the deepest inland lake in Michigan (Michigan.gov 2021) and is a typical oligotrophic lake. Kociolek and Stoermer (2009) have suggested that, as opposed to aquatic systems with significant ecological disturbances, oligotrophic systems may be comparatively ignored by taxonomists and ecologists.

In recent years, Torch Lake and several other oligotrophic lakes in northern Michigan have experienced increased growth of littoral benthic algae. In conversation with local lake shore residents, we learned that the once white "sugar" sands of the littoral zone had gradually become covered with a golden-brown growth of algae. In 2014 this led us to pursue experimental research using nutrient diffusing substrates to determine the cause of this increased algal growth. In the course of that investigation, we discovered that the golden-brown growth was a rich and diverse assemblage of diatoms, several of which appeared to be new species.

The purpose of the present report is to document the benthic diatom flora of Torch Lake based on samples taken in the summer of 2014. We present detailed light and scanning electron microscopy observations on 11 taxa, six of which are

new to science and an additional three of which constitute new reports for the United States. In addition, a new combination for another taxon is proposed.

METHODS AND MATERIALS

Torch Lake, located at 44°59'00"N, 85°18'30"W, is 2 km wide and 31 km long. It is Michigan's longest lake, and, with its maximum depth of just under 100 m, it is the deepest inland lake in Michigan. It is part of a chain of lakes, including Lake Bellaire and Clam Lake upstream and Skegemog Lake and Elk Lake downstream. This chain empties into Grand Traverse Bay of Lake Michigan.

Benthic diatoms were collected from a variety of substrates, including visible streaks of golden brown, from sites along the eastern shoreline in the summer of 2014. Collection sites for this study were designated as Sites 1 (44°53'06"N; 85°16'48"W), 2 (45°57'09"N; 85°16'54"W), and 3 (45°02'55"N, 85°18'45"W). The samples were put on ice and returned to the lab for processing. Samples were cleaned by the hydrogen peroxide method of Van der Werff (1953) and decanted, rinsed, and settled five times for 24 hours each. For LM observations, the cleaned material was settled onto glass coverslips, air-dried, and mounted in Naphrax for permanent slides. LM observations were made with an Olympus BX-51 light microscope (Olympus America Inc., Center Valley, Pennsylvania, USA) with 1.42NA 60X and 1.40NA 100X objectives and with Differential Interference Contrast optics.

For SEM observations, cleaned material was air dried onto glass coverslips and mounted onto aluminum stubs. The stubs were coated with ca. 1.5 nm of gold using a Cressington 108 auto sputter coater (Cressington Scientific Instruments Ltd., Watford, UK). All SEM images were taken using a JEOL (Tokyo, Japan) JSM 7401 field emission SEM at an acceleration voltage of 3 kV at the Nano Characterization Facility at the University of Colorado, Boulder.

Images were captured with an Olympus BX-71 digital camera, and images were processed with GIMP software.

All collections associated with this work are deposited in the Diatom Collection of the University of Colorado, Boulder (COLO). Holotypes are deposited at COLO and isotypes are deposited at the Diatom Herbarium of the Academy of Natural Sciences of Drexel University in Philadelphia, Pennsylvania (ANSP).

RESULTS

A total of 176 diatom taxa in 58 genera have been identified from the six benthic samples taken from Torch Lake in 2014 and are listed in Table 1. New and otherwise interesting species are discussed below.

Lindavia praetermissa (Lund) Nakov et al. (Figures 1–8).

Description: Valves are 10–40 µm in diameter. There are ca. 14–20 striae in 10 µm. Marginal fultoportulae number 3–5 / 10 µm, while there are 2 or 3 isolated valve face fultoportulae present. One or 2 rimoportulae are present on the valve face, located at the end of shortened striae. Figure 1 illustrates an initial valve of this species.

Comments: Krammer and Lange-Bertalot (1991a) and Kiss et al. (2012) both give a range of 8–25 µm for the diameter of this species, and this range was expressed in the Torch Lake population (Plate 1). This species was originally placed in the genus *Cyclotella*, but has since been transferred to *Puncticulata* by Håkansson (2002) and to *Handmannia* by Khursevich and Kociolek (2012). A phylogenetic analysis led Nakov et al. (2015) to transfer this species to the genus

TABLE 1. Diatom taxa found in three sites along the eastern shore of Torch Lake in collections on July 1 and 7, 2014. An X indicates presence of that taxon at that site on that date.

Taxon	Site 1 July 7	Site 2 July 1	Site 3 July 7	Site 4 July 1	Site 5 July 7
Achnanthyidium gracillima (F.Meister) Lange-Bertalot	X	X	X		X
Achnanthyidium exiguum (Grunow) Czarnecki				X	
Achnanthyidium jackii Rabenhorst	X	X		X	
Achnanthyidium minutissimum (Kützing) Czarnecki	X	X	X	X	X
Achnanthyidium rosenstockii (Lange-Bertalot) Lange-Bertalot	X			X	X
Amphora oligotraphenta Lange-Bertalot				X	
Amphora ovalis (Kützing) Kützing		X			
Amphora michiganensis Stoermer & Yang	X		X		
Amphora oligotraphenta Lange-Bertalot	X		X		
Amphora pediculus Grunow ex Schmidt	X	X		X	X
Aneumastus pseudotusculus (Hustedt) E.J.Cox & D.M.Williams				X	
Aneumastus tusculus f. minor (Hustedt) Bukhtiyarova	X	X		X	
Anuemastus tusculus f. tusculus (Ehrenberg) D.G.Mann & Stickle	X	X	X	X	
Asterionella formosa Hassall	X	X	X		
Brachysira brebissonii R.Ross		X	X		X
Brachysira neoexilis Lange-Bertalot	X	X	X	X	X
Brachysira ontonagensis Anderson et al.	X	X	X	X	
Brachysira sp.	X			X	
Brachysira vitrea (Grunow) Ross					X
Caloneis bacillum (Grunow) Cleve				X	
Caloneis silicula var. silicula (Ehrenberg) Cleve		X	X		X
Caloneis silicula var. truncata (Grunow) F.Meister					X
Caloneis obtusa (W.Smith) Cleve		X		X	
Caloneis tenuis (Gregory) Krammer	X		X	X	X
Chamaepinnularia hassiaca (Krasske) Cantonati & Lange-Bertalot				X	
Chamaepinnularia sp.					
Cocconeis pediculus Ehrenberg		X			X

(Continued on next page)

TABLE 1. (Continued)

Taxon	Site 1 July 7	Site 2 July 1	Site 3 July 7	Site 4 July 1	Site 5 July 7
Cocconeis placentula Ehrenberg	X			X	
Cocconeis pseudothumensis E.Reichardt	X			X	
Cyclotella atomus Hustedt		X	X		
Cyclotella comensis Grunow	X	X	X	X	X
Cyclotella distinguenda Hustedt	X	X	X	X	
Cymatopleura norvaldorum Kociolek et al., sp. nov.		X			X
Cymbella gibbosa (Brun) F.Meister	X			X	
Cymbella aspera (Ehrenberg) H. Peragallo		X		X	
Cymbella austriaca Grunow		X			
Cymbella cistula (Ehrenberg) Kirchner	X			X	X
Cymbella citrus Carter & Bailey-Watts	X			X	X
Cymbella hustedtii Krasske	X	X	X	X	X
Cymbella leptoceros (Ehrenberg) Kützing	X		X		
Cymbella proxima Reimer					X
Cymbella torchiana Kociolek et al., sp. nov.				X	
Cymbella sp.				X	X
Cymbella subaequalis Grunow	X		X		
Cymbellafalsa diluviana (Krasske) Lange-Bertalot & Metzeltin	X				
Cymbopleura naviculiformis (Auerswald ex Heiberg) Krammer	X				
Delicatophycus delicatula (Kützing) Wynne	X	X	X	X	X
Denticula elegans Kützing		X			X
Denticula tenuis Kützing		X			X
Diatoma ehrenbergii Kützing	X	X	X	X	X
Diatoma elongatum (Lyngbye) C.A.Agardh	X	X	X	X	
Diatoma hiemale (Roth) Heiberg			X		
Diploneis finnica (Ehrenberg) Cleve			X		
Diploneis marginstriata Hustedt		X			X
Diploneis subovalis Cleve	X	X			

TABLE 1. (Continued)

Taxon	Site 1 July 7	Site 2 July 1	Site 3 July 7	Site 4 July 1	Site 5 July 7
Gomphoneis olivacea (Hornemann) P.A.Dawson ex R.Ross & P.A.Sims		X		X	
Gomphonema cf. rosenstockianum Lange-Bertalot & E.Reichardt				X	
Gomphonema acuminatum Ehrenberg					X
Gomphonema coronatum Ehrenberg				X	
Gomphonema melfii Kociolek et al., sp. nov.	X	X	X	X	X
Gomphonema micropus Kützing					
Gomphonema minusculum Krasske				X	X
Gomphonema subtile Ehrenberg	X	X		X	X
Gomphonema truncatum var. elongata (M.Peragallo & Héribaud) R.M.Patrick				X	
Gomphonema tumens Kociolek & Stoermer		X			
Gomphonema vibrio Ehrenberg	X	X	X		
Gyrosigma sp.	X				
Halamphora thumensis (A.Mayer) Levkov				X	
Karayevia clevei (Grunow) Round & Bukhtiyarova				X	
Kobayasiella sp.		X	X		X
Kobayasiella jaagii (Meister) Lange-Bertalot	X				
Lindavia praetermissa (Lund) Nakov et al.	X	X	X	X	X
Mastogloia grevillei W.Smith	X	X			
Mastogloia lacustris (Grunow) Van Heurck		X	X	X	X
Mastogloia smithii Thwaites ex W.Smith		X	X	X	
Meridion circulare (Greville) C.A.Agardh	X	X		X	
Navicula capitoradiata Germain				X	
Navicula concentrica Carter & Bailey-Watts				X	
Navicula cryptotenella Lange-Bertalot	X	X	X	X	X
Navicula hasta Pantocsek					X
Navicula medioconvexa Hustedt	X				
Navicula oblonga Ehrenberg		X		X	X
Navicula radiosa Kützing	X		X	X	X
Navicula reinhardtii (Grunow) Grunow	X				
Navicula schadei Krasske					
Navicula tripunctata Bory				X	
Navicula vulpina Kützing	X			X	X

TABLE 1. (Continued)

Taxon	Site 1 July 7	Site 2 July 1	Site 3 July 7	Site 4 July 1	Site 5 July 7
Rhopalodia gibba (Ehrenberg) O.Müller	X	X		X	X
Sellaphora aggerica (E.Reichardt) Falasco & Ector	X	X	X		X
Sellaphora mutata (Krasske) Lange-Bertalot					X
Sellaphora pupula (Kützing) Mereschkowsky	X				
Sellaphora sp.		X			
Sellaphora stroemii (Hustedt) H.Kobayasi	X		X		
Stauroneis lauenburgiana Hustedt		X			
Stauroneis sibirica (Grunow) Lange-Bertalot & Krammer	X				X
Staurosira construens Ehrenberg	X				
Staurosira elliptica (Schumann) D.M.Williams & Round	X				
Staurosirella lapponica (Grunow in Van Heurck) D.M.Williams & Round					X
Staurosirella martyi (Héribaud) Morales & Manoylov	X				
Staurosirella rhomboides (Grunow) Morales & Manoylov				X	
Stephanocostis chantaicus Genkal & Kuzmina	X		X		X
Stephanodiscus alpinus Hustedt	X	X	X		X
Stephanodiscus hantzschii Grunow					
Surirella linearis W.Smith	X				
Tabellaria fenestrata (Lyngbye) Kützing	X	X			
Ulnaria delicatissima (W.Smith) M.Aboal & P.C.Silva					X
Ulnaria ulna (Nitzsch) Compere	X				

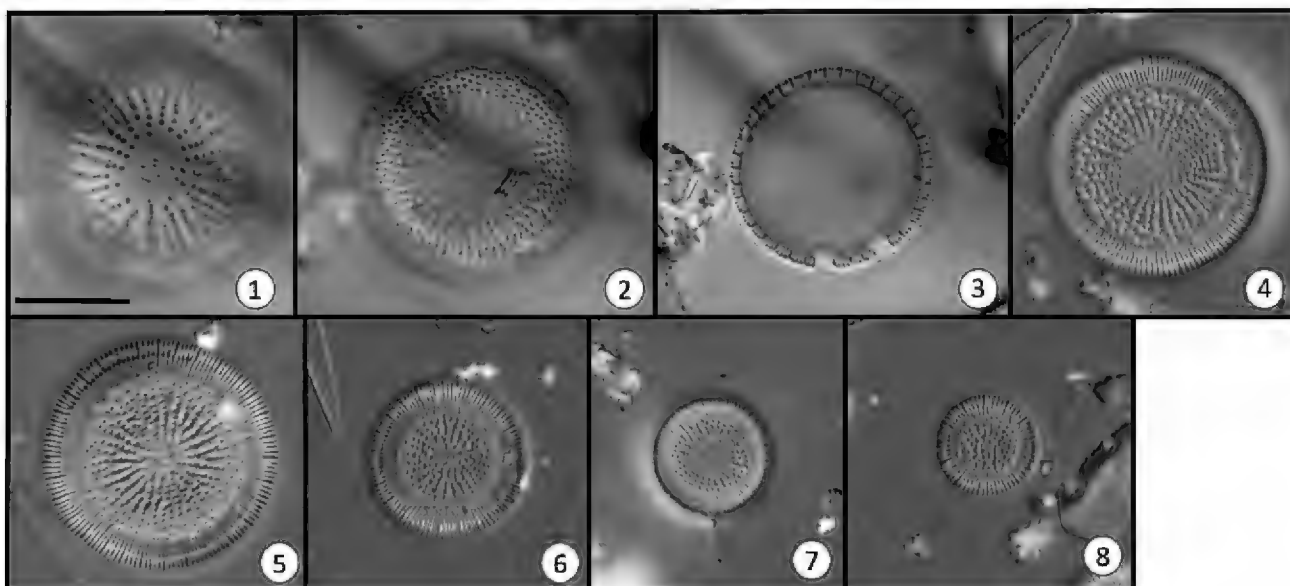


Plate 1. Figures 1–8. *Lindavia praetermissa* (Lund) Nakov et al. LM. Size diminution series, valve views. Scale bar = 10 μm .

Lindavia. Houk et al. (2010) and Kiss et al. (2012) have argued for its retention in *Cyclotella*.

Kiss et al. (2012) report this taxon from meso- to eutrophic systems in Hungary. This difference in ecological preferences or tolerances between the North American and European populations suggests that further work may show that these populations are taxonomically distinct at some level.

Fragilaria perdelicatissima Lange-Bertalot & Van de Vijver (Figures 9–21).

Description: Valves are narrowly lanceolate, tapering to a fine end with knob-like apices. Length ranges from 20.0–78.5 μm , breadth is 2–4 μm . The central sternum is in the shape of the valve. A central area may be rectangular, unilaterally expanded, or not evident. Striae are short, approximately the same length through the entire length of the valve, occur opposite one another, and number 12–16 / 10 μm . Individual areolae are not resolved in the LM.

In the SEM, the valve exterior displays areolae that are oriented with the longitudinal axis; each areola is constricted in the middle (Figures 16–18). There is a single rimoportula on the valve, positioned near the apex (Figure 17); the opening of the rimoportula is larger and more elliptical than the individual areolae. A small ocellimbus is present on the mantle of both apices. Ghost striae are present in the central area, though the center is not tumid on one or both margins (Figure 16). Internally (Figures 19–21), the central sternum is wide in the center and tapers to both apices. Areolae are unoccluded and appear to be oriented alternate from one side of the central sternum to the other (Figure 21). At one end, the rimoportula has a thickened border (Figure 19).

Comments: This species is distinguished from *F. nanana* Lange-Bertalot in its shorter length and coarser striae; *F. nanana* is reported to have 22–25 (–30) striae / 10 μm (Krammer and Lange-Bertalot 1991a). It is distinguished from *F. tenera* (W. Smith) Lange-Bertalot by having a narrowly lanceolate outline. Krammer and Lange-Bertalot (1991a, plate 115, figures 1–5) illustrate *F. tenera* showing

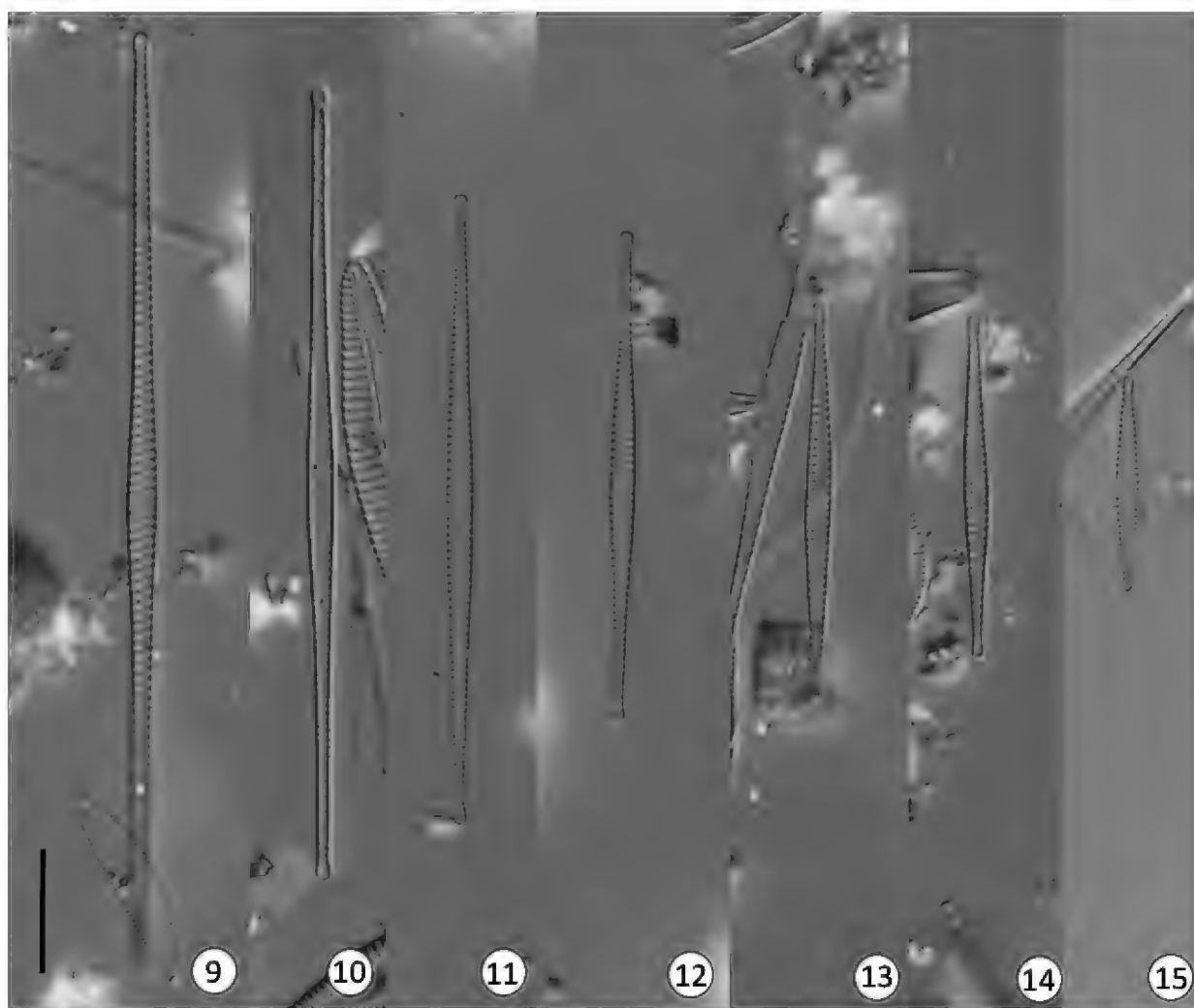


Plate 2. Figures 9–15. *Fragilaria perdelicatissima* Lange-Bertalot & Van de Vijver. LM. Size diminution series, valve views. Scale bar = 10 μm .

its parallel margins that taper abruptly to the knob-like apices. Specimens from Torch Lake are slightly shorter than the lengths given in the original description (36–95 μm) and are slightly wider (up to 4 μm versus up to only 2.6 μm). Otherwise, the specimens look very similar to the type population from Ireland.

This is the first reported occurrence of this species in the United States.

Fragilaria pettyorum Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek, n. sp. (Figures 22–26).

Description: Valves are linear-lanceolate, tapering gradually to protracted, knob-like ends, with length 32–55 μm and breadth 3–4 μm . The central sternum is narrowly lanceolate and expanded at the center to form a distinct central area with either an equal or unequal fascia, then expanded to both or just one margin. The fascia may contain or lack ghost striae. The striae are distinct, coarse, alternate, without distinct puncta, 8–11 / 10 μm . No processes are evident in the LM.

In the SEM, the valve interior has a unilaterally expanded central area (Figure 25). The areolae are rounded and unoccluded. The central sternum tapers from the wide center to becoming narrow at the apices. There is a single rimo-

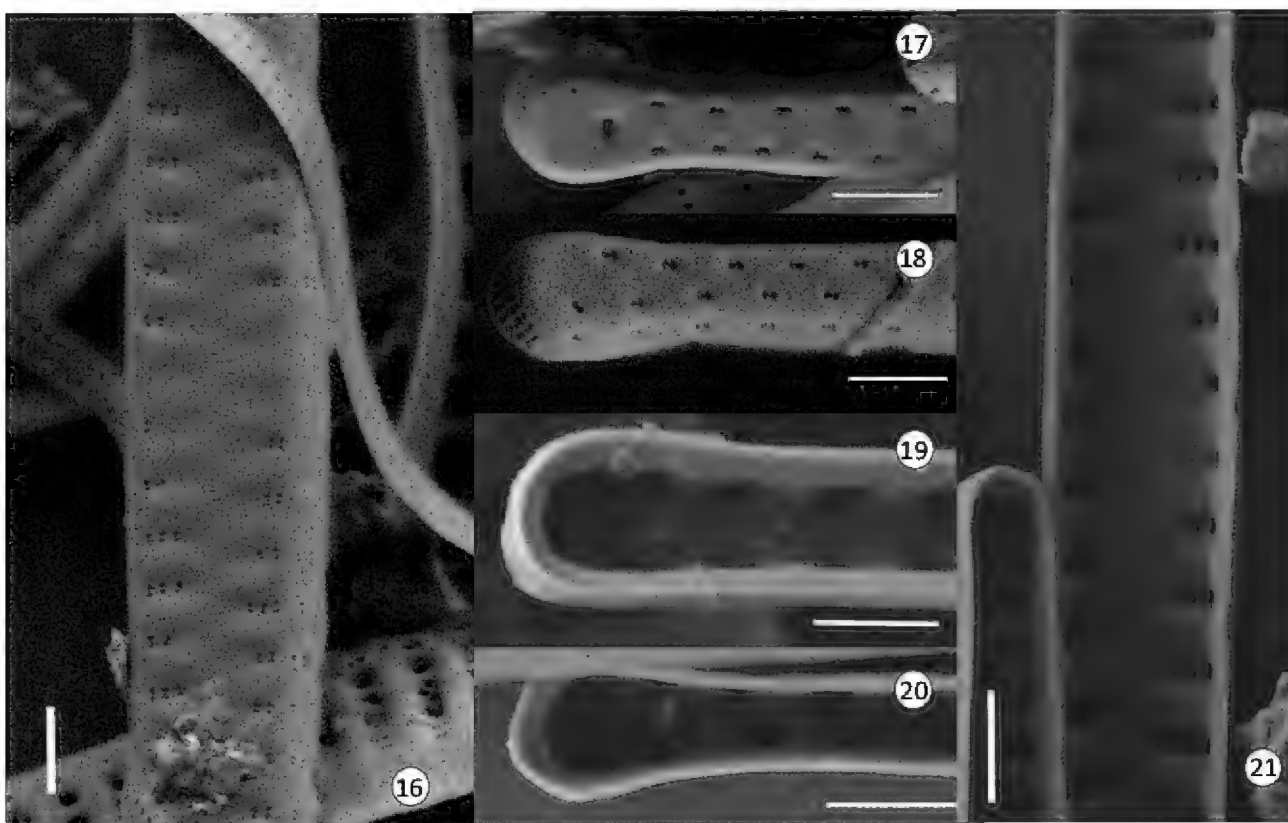


Plate 3. Figures 16–21. *Fragilaria perdelicatissima* Lange-Bertalot & Van de Vijver. SEM. Figs 16–18: external views. Fig. 16. Central area of the valve. Striae are composed of 2–4 variously-shaped areolae. Scale bar = 1 µm. Fig. 17. Valve terminus with prominent opening of labiate process evident; on the mantle is an ocellimbus. Scale bar = 1 µm. Fig. 18. Valve terminus without labiate process; The areolae have small siliceous projections from the margin; the ocellimbus is obvious on the mantle. Scale bar = 1 µm. Figs 19–21: internal views. Fig. 19. Valve terminus with distinct labiate process. Scale bar = 1 µm. Fig. 20. Valve terminus lacking labiate process. Scale bar = 1 µm. Fig. 21. Central area of the valve, with striae comprised of 1–3 areolae. Scale bar = 1 µm.

portula, located on the valve face at one apex. The rimoportula has a thickened border. Pseudosepta are present at the apices (Figures 25, 26).

Holotype: Slide 650055 deposited at COLO.

Isotype: Slide GC59343 deposited at ANSP.

Comments: According to the grouping of those pennate diatoms lacking a raphe by Krammer and Lange-Bertalot (1991), this would be part of the group they referred to as the “*Fragilaria capucina*” group. It is most similar to the taxon they refer to as “*F. capucina* v. *amphicephala* (Grunow) Lange-Bertalot,” a name that is incorrect, since Kützing is the author of the basionym of this taxon (*F. amphicephala* Kützing). Krammer and Lange-Bertalot (1991a, plate 109, fig. 20) illustrate the lectotype of Kützing’s taxon, which seems to lack an inflated central area. The survey of the types of the *Fragilaria vaucheriae*–*F. intermedia* complex by Tuji and Williams (2013) does not offer any taxa that approach the shape or size of *F. pettyorum*. Our images match up best to an unnamed group of specimens listed as “*Fragilaria distans* / fragilarioids Sippe” in Krammer and Lange-Bertalot (1991a, plate 112, figures 16–21).

Etymology: Named in honor of Lyn and Gary Petty, who offered support and graciously provided access to Torch Lake through their property.

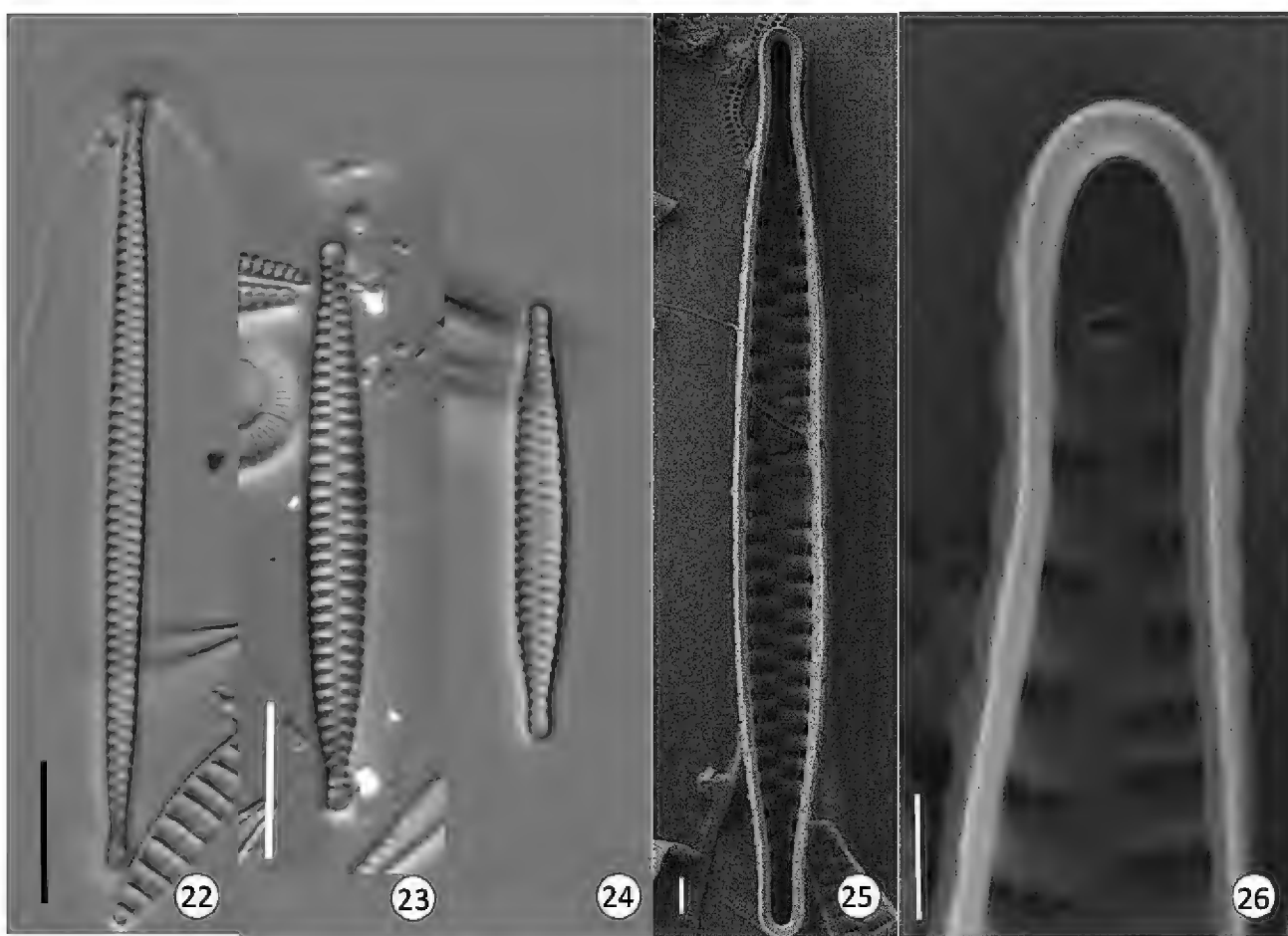


Plate 4. Figures 22–26. *Fragilaria pettyorum* Kociolek et al. LM and SEM. Figs 22–24: LM, valve views. Fig. 22 is of the holotype. Scale bar = 10 μ m. Figs. 25 and 26: SEM, internal views. Fig. 25. Whole valve view showing striae composed of 2–4 areolae, occluded internally; at each end of the valve is a pseudoseptum. Scale bar = 1 μ m. Fig. 26. One apex of the valve, showing the labiate process and the distinct pseudoseptum. Scale bar = 1 μ m.

Eunotia alkalibiontica Lange-Bertalot (Figures 27–35).

Description: Valves have arched margins, with the dorsal margin being convex and the ventral margin being strongly concave. The apices are distinctly protracted and become slightly broader at the ends. Apices are angular to rostrate. Valves are 32–50 μ m in length and 6–8 μ m in breadth. Striae are indistinctly punctate, parallel, and interrupted near the ventral margin. Striae number 6–8 / 10 μ m in the center of the valve, 11–13 / 10 μ m at the ends. External distal raphe ends are evident at the ventral margin, extending ca. 1/3 of the way towards the dorsal margin.

In the SEM, the exterior of the valve face (Figure 32) has striae composed on rounded areolae. The areolae extend across the valve face and are interrupted near the valve face–mantle junction, then reoccur on the mantle. Striae are denser on the mantle than on the valve face (Figure 35). Distal raphe branches curve slightly from the mantle onto the valve face. One valvocopula and two pleurae are associated with a valve. The girdle elements have many poroids that align with the striae of the valve (Figure 35). Internally, striae appear to occur in grooves, which ultimately bifurcate (Figure 33). The internal edge of the valve

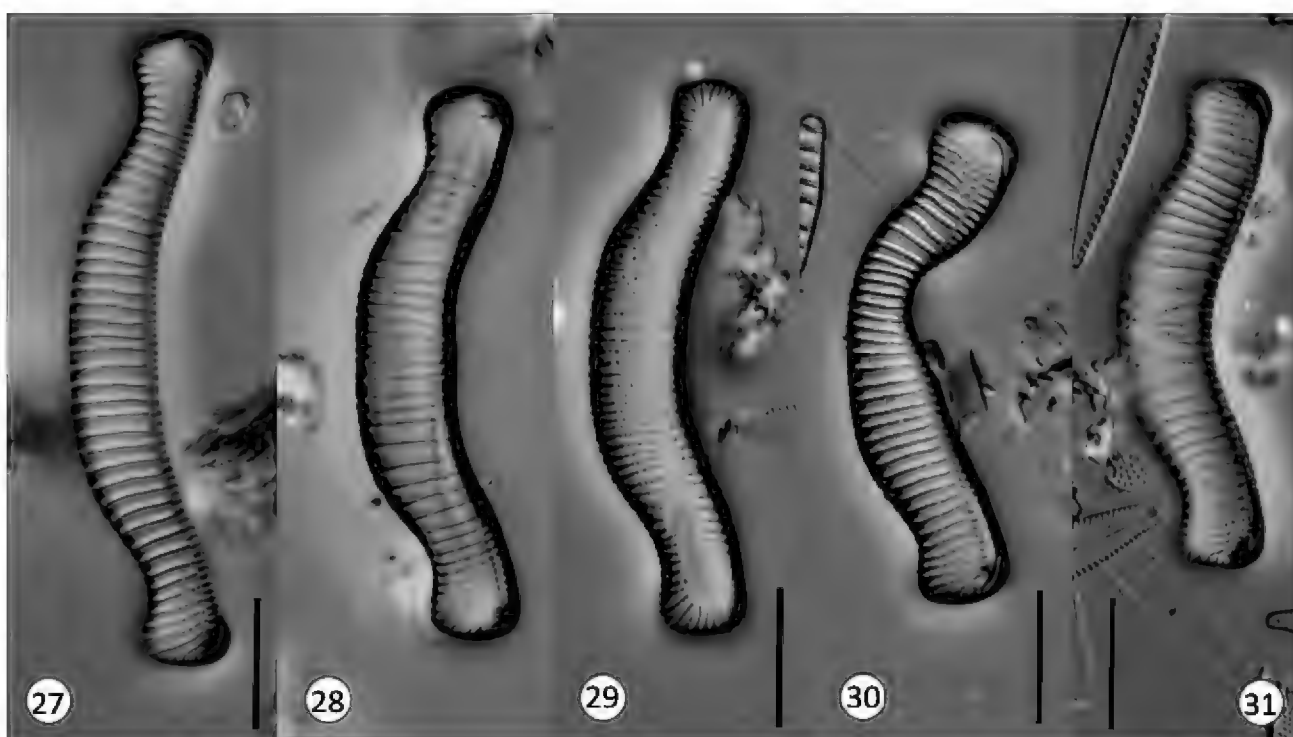


Plate 5. Figures 27–31. *Eunotia alkalibiontica* Lange-Bertalot. LM. Size diminution series, valves views. Fig. 28 shows irregular spacing of striae. Fig. 29 shows the valve without a raphe. Fig. 30 show teratology in valve outline. Fig. 31 shows teratology in striae. Scale bars = 10 μ m; the scale bar in Fig. 27 also applies to Fig. 28.

mantle is fimbriate (Figure 34). Helictoglossae are not prominent, and no rimoportula has been observed.

Comments: Many of the Torch Lake specimens of *E. alkalibiontica* possess some type of teratology, sometimes in valve outline (Figures 28–31), sometimes in the density and orientation of the striae (Figure 28), or sometimes in the complete absence of the raphe system (Figure 29). Lang-Bertalot et al. (2011) do not mention this tendency of *E. alkalibiontica* in either the description or the illustrations of this species. Beals and Potapova (2013) compared this species to *Eunotia arcuoides* Foged, another member of the genus found in alkaline waters but possessing amphoroid symmetry, where there the girdle elements are wider on the dorsal side of the valve as compared to the ventral side of the valve. Both species have highly arched valve margins. But the amphoroid symmetry is lacking in *E. alkalibiontica*, as are rimoportulae. The helictoglossae of *Eunotia arcuoides* also have a unique rounded structure that is not present in those of *E. alkalibiontica*.

Eunotia alkalibiontica is not unique in the Eunotiales in lacking rimoportulae; this situation is known in some other members of *Eunotia*, as well as in some other members of the order, including *Bicudoa* (Wetzel et al. 2012) and some taxa of *Actinella* (Kocielek and Rhode 1998). Presence of rimoportulae in the Eunotiales, the earliest branch in the raphid diatom tree of life, is suggested to be primitive (Hustedt 1952; Kocielek 2000), thus it seems likely the lack of rimoportulae in certain members of the order is due to independent secondary loss.

This is the first report of this species in the United States.

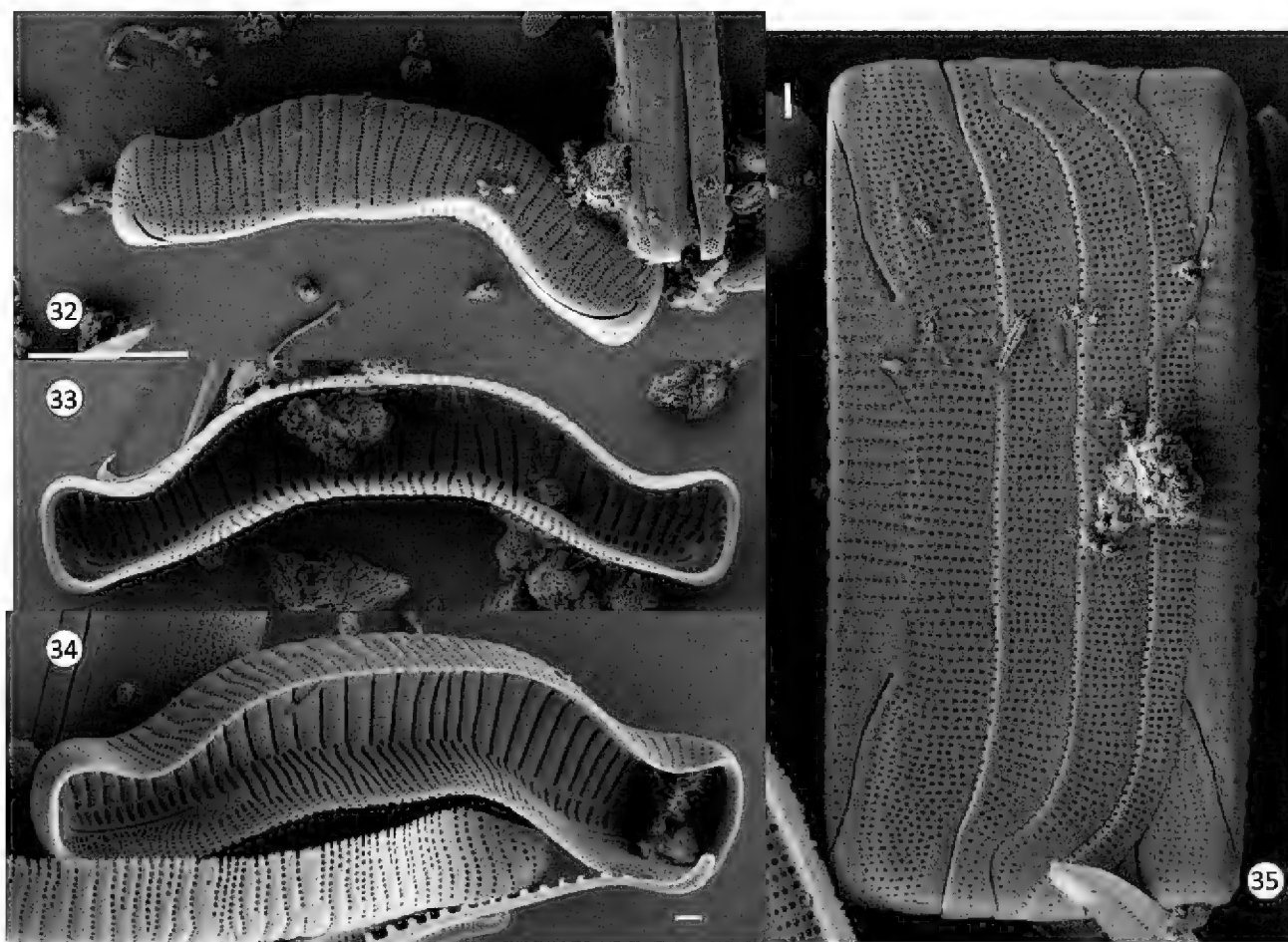


Plate 6. Figures 32–35. *Eunotia alkalibiontica* Lange-Bertalot. SEM. Figs 32, 33. Valve exterior. Fig. 32. Valve view, with punctate striae and distal raphe end evident. Scale bar = 10 μm . Figs. 33, 34. Internal views. Both images show the presence of elongated and shortened striae on dorsal and ventral mantles. The raphe terminates as helictoglossae. Labiate processes are absent. Scale bar in fig. 34 = 1 μm , for both figures. Fig. 35. Girdle view. The raphe is evident on the valve mantle of both valves present. Cingula elements have poroids that are organized into striae. Scale bar = 1 μm .

Sellaphora aggerica (E.Reichardt) Falasco & Ector (Figures 36–42).

Description: Valves are oblong, having margins that are straight to barely convex and apices that are rounded and not protracted. Valve length is 14–27 μm and breadth is 3.0–5.5 μm . The axial area is narrow, expanded to form an asymmetrical, elliptical to round central area. Along the axial area on both sides is a hyaline area, a longitudinal trough or depression, running the length of the valve, which can be pronounced or negligible in its development. The raphe is straight, filiform and, as seen in the LM, does not reach the apices. The external proximal raphe ends barely enter the central area. Striae are curved, radiate, 24–27 / 10 μm , not distinctly punctate. The striae are slightly coarser around the central area.

In the SEM, the valve exterior (Figure 41) shows the valves to have shallow grooves on either side of the axial area, the punctate striae extend into the grooves. The raphe is straight, with dilated proximal ends and distal ends that are deflected onto and extend across the mantle. Striae extend onto the valve mantle. The mantle has a fimbriate margin. Internally (Figure 42), the raphe is straight, with proximal ends terminating with a slight thickening. Distal raphe

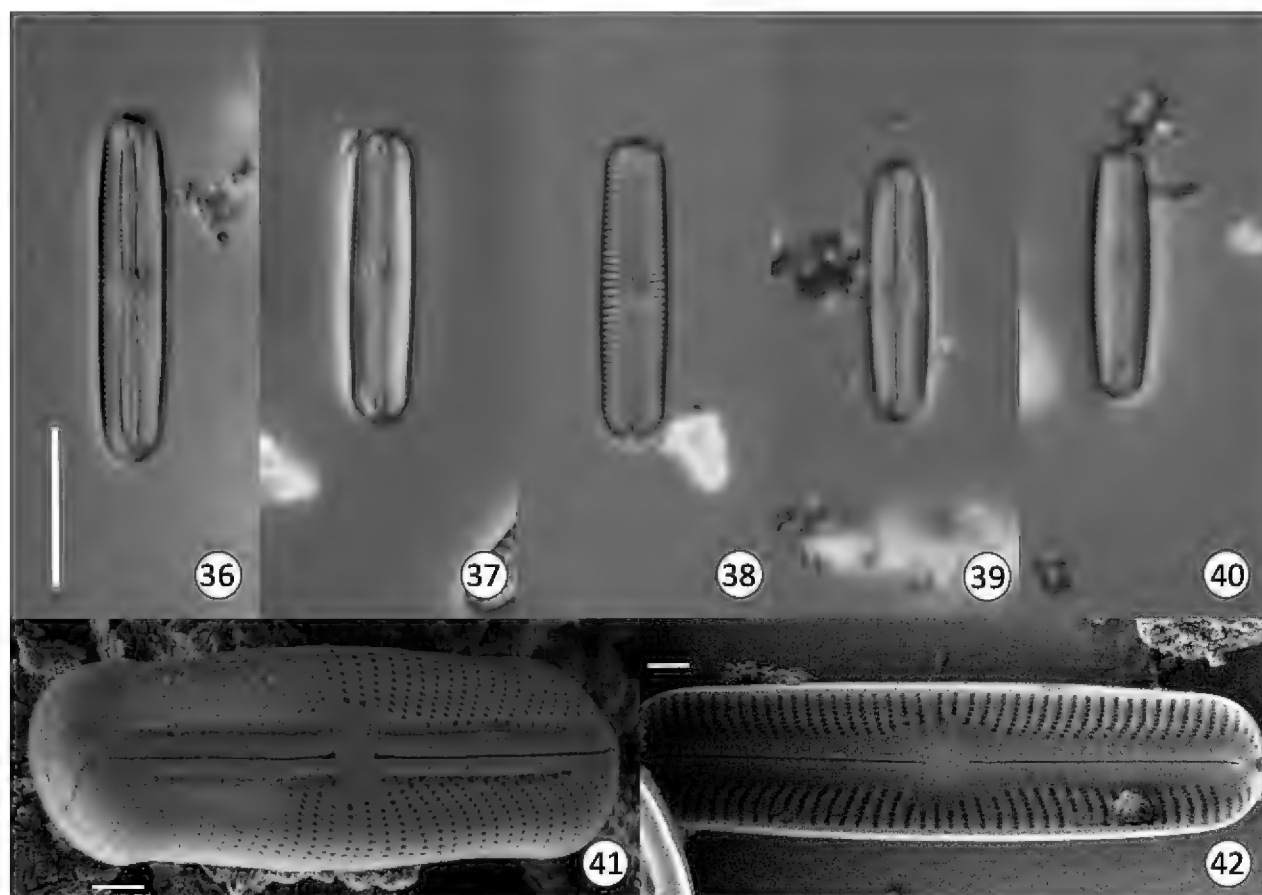


Plate 7. Figures 36–42. *Sellaphora aggerica* (E.Reichardt) Falasco & Ector. LM and SEM. Figs 36–40, LM. Size diminution series, valve views. Scale bar = 10 µm. Figs 41, 42, SEM. Fig. 41. Valve exterior, with grooves running apically along either side of the axial area. The distal raphe end is hooked onto the valve mantle. Scale bar = 1 µm. Fig. 42. Valve interior, showing a straight raphe, a small central nodule, the raphe terminating as helictoglossae, and a small, round depression on the valve mantle at the apex. Scale bar = 1 µm.

ends terminate as helictoglossae. There is a round depression located at each terminus.

Comments: Wetzel et al. (2015) report this species as being 7.4–16.7 µm long, 3.2–3.5 µm wide, and with 24–29 striae / 10 µm. Our specimens are longer and wider than those reported by Wetzel et al. (2015) and by Falasco et al. (2009). This species resembles *S. stroemii* (Hustedt) H. Kobayasi (as *Navicula stroemii* Hustedt); see, e.g., Krammer and Lange-Bertalot 1986, plate 69, figs. 1–10; Lange-Bertalot and Metzeltin 1996, plate 83, figs 14–16), but differs in the shape of the valve, which is relatively narrow in *S. aggerica* and lacks protracted apices.

This is a new record for the United States.

Gomphonema melfii Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek, n. sp. (Figures 43–52).

Description: Valves are linear-lanceolate-clavate to lanceolate-clavate in shape and have apices that are rounded, not expanded. Valve length is 20–61 µm, and valve breadth is 4–8 µm. The axial area is narrow at the poles, widening towards the center where it forms a laterally-expanded, rectangular central area. There are 1–2 very short striae on either side of the central area. A small, round

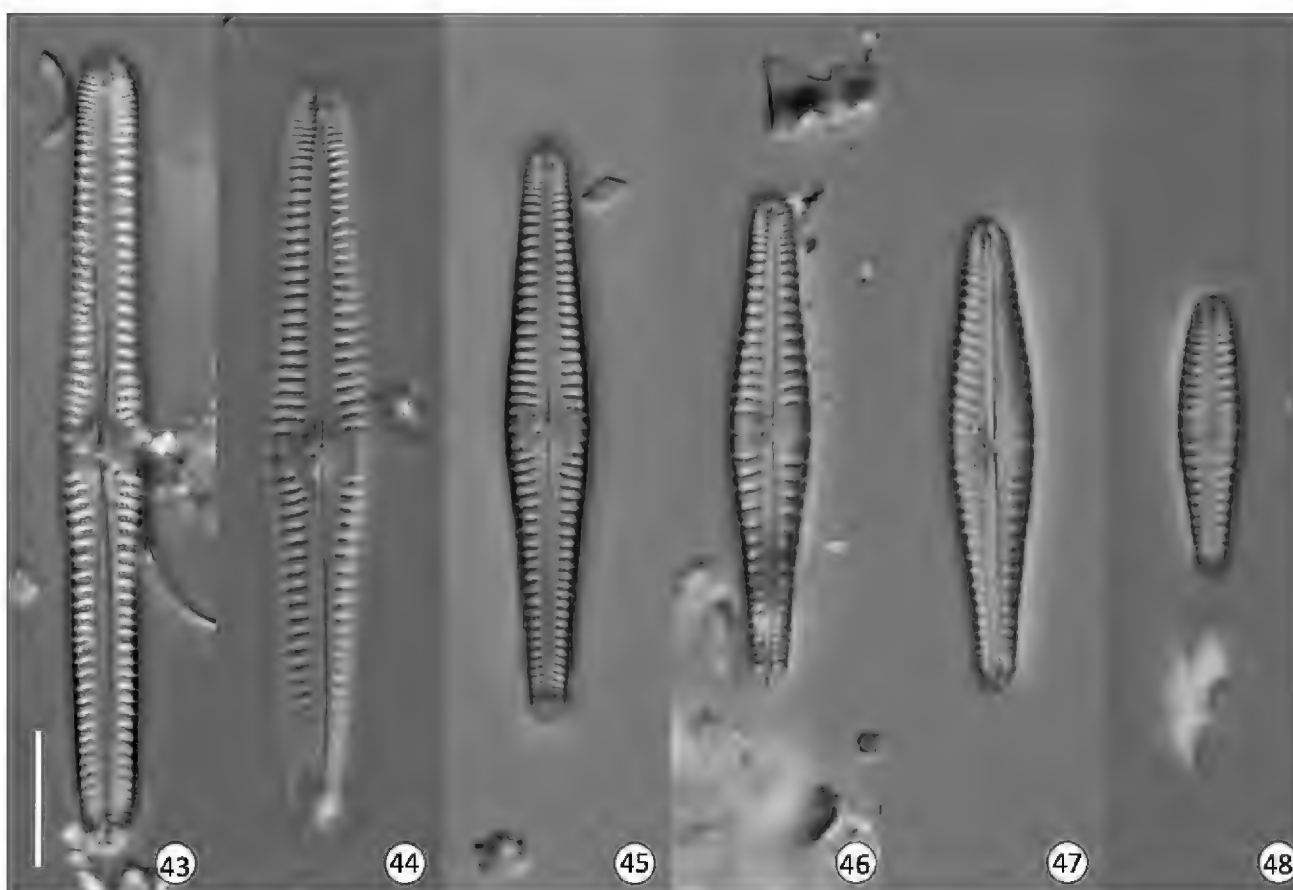


Plate 8. Figures 43–48. *Gomphonema melfii* Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek. LM. Size diminution series, valve views. Figure 43 is of an initial valve. Fig. 45 is of the holotype. Scale bar = 10 μ m.

isolated stigma opening is present in the central area. The raphe is lateral and straight. The external proximal ends of the raphe are dilated slightly, rounded, and terminate close to one another. External distal raphe ends are deflected onto the valve mantle towards the side opposite the stigma. Striae are not punctate, radiate, 14–20 / 10 μ m, and become denser towards the headpole. The apical pore field is bilobed and evident at the footpole. Septa and pseudosepta are present.

In the SEM, the valve interior has a lanceolate axial area. Relatively large pseudosepta are present at the apices (Figures 49, 50). Helictoglossae are large, slightly offset from the raphe slit (Figures 49, 52). The central nodule appears to be two mounds, with strongly recurved proximal raphe ends. The stigma is round and occluded. Areolae are occluded internally (Figures 49, 51).

Holotype: Slide 650056 deposited at COLO.

Isotype: Slide GC 59344 deposited at ANSP.

Comments: This species is differentiated from *G. lateripunctatum* Reichardt & Lange-Bertalot by the shape of the valves and that *G. lateripunctatum* has an expanded headpole (Reichardt and Lange-Bertalot 1991; Lange-Bertalot and Metzeltin 1996, plate 98, figs. 20–23). A recent report of *G. lateripunctatum* from Macedonia supports the original concept of the taxon (Levkov et al. 2016). The Macedonia records of *G. lateripunctatum* are from peat bogs. Cantonati et al. (2012) report this same species from alkaline springs in the Italian alps. It may well be that the specimens reported by Cantonati et al. (2012) are the same species as those from Torch Lake.

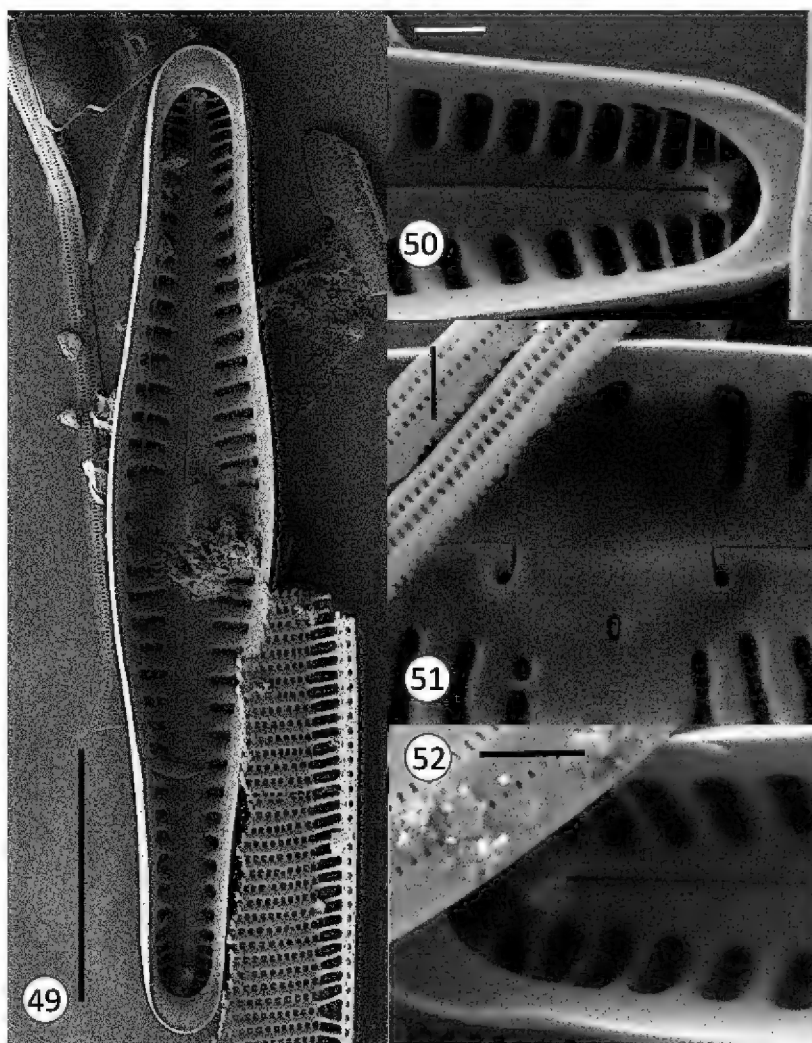


Plate 9. Figures 49–52. *Gomphonema melfii* Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek. SEM, internal views. Fig. 49. Whole valve, with evident helictoglossae and pseudosepta at the poles. Scale bar = 10 μm . Fig. 50. Headpole, showing large helictoglossae offset from the raphe slit, condensed striae and pseudoseptum. Scale bar = 1 μm . Fig. 51. Central nodule, with proximal raphe ends hooked and a rounded, occluded stigma opening evident. The areolae of the striae also have internal occlusions. Scale bar = 1 μm . Fig. 52. Footpole, with evident helictoglossa and pseudoseptum. Scale bar = 1 μm .

The denser striae at the headpole and the internal position of the occlusions of the areolae suggest an affinity with the *G. intricatum* group of gomphonemoid diatoms (Kociolek and Stoermer 1990, 1991; Reichardt and Lange-Bertalot 1991; Kociolek and Stoermer 1993; You et al. 2015).

Etymology: Named in honor of the late John Melfi, a distinguished fisherman and nature lover who spent his summers at Torch Lake.

Encyonopsis sp. (Figures 53–57).

Description: Valves are asymmetrical to the apical axis. The dorsal margin is convex while the ventral margin is straight to barely tumid in the center. The apices are slightly protracted and bent ventrally. Length of the valves is 17–29 μm , and breadth is 3.5–4.0 μm . The axial area is narrow, straight, becoming a barely differentiated, elliptical central area. The raphe is slightly lateral and has external proximal raphe ends that are dilated and deflected towards the dorsal margin. The external distal raphe ends are deflected towards the ventral margin.

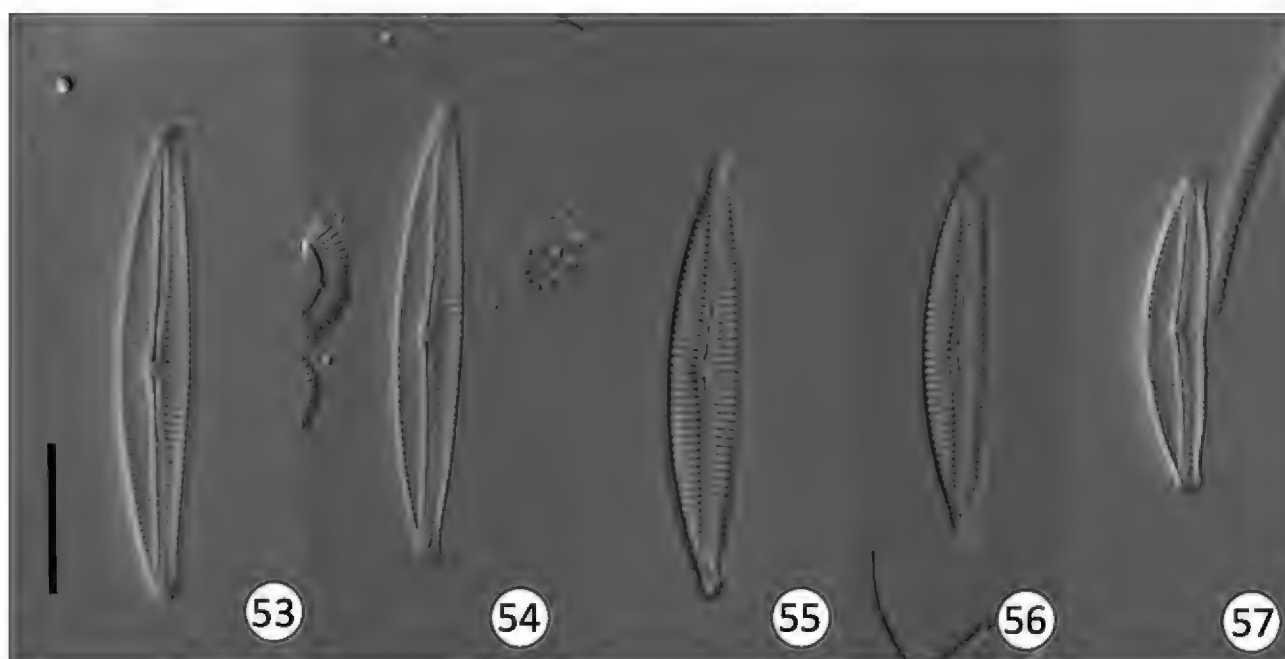


Plate 10. Figures 53–57. *Encyonopsis* sp. LM. Size diminution series, valve views. Scale bar = 10 μm .

Striae are not punctate. The striae are radiate on the dorsal margin, radiate in the center and parallel near the apices on the ventral margin, 19–23 / 10 μm . A stigma is lacking.

Comments: This species is distinguished from *Encyonema evergladianum* Krammer by the more slender valves, which are reported in the original description (Krammer 1997) as 30 μm long and 5 μm wide and by Mazzei (2014) as 33 μm long and 6 μm wide.

We propose a new combination for Krammer's taxon within the genus *Encyonopsis* as described by Krammer (1997), based on its small size, relatively reduced valve asymmetry, and raphe structure as compared to *Encyonema*:

Encyonopsis evergladianum (Krammer) Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek, comb. nov.

Basionym: *Encyonema evergladianum* Krammer (1997), pp. 73–74, Plate 142, figures 1–7.

The Torch Lake population also resembles *Encyonema krammeri* Reichardt in the shape and width of the valves, but it differs in the shape of the apices (Reichardt 1997; Krammer 1997). Further work is warranted to determine whether the Torch Lake population should be recognized as a new species.

Cymbella heterogibbosa H. Kobayasi & Mayama (Figures 58–67).

Description: Valves are strongly arched and asymmetrical to the apical axis. The ventral margin is distinctly tumid and the apices are not protracted. Valve length is 77–135 μm and breadth is 19–23 μm . The axial area is positioned slightly towards the ventral margin, arched, and follows the outline of the valve. The axial area is expanded to form a linear but distinct central area. The raphe is lateral and becomes reverse lateral at the center and near the apices. External proximal raphe ends are dilated, rounded and deflected towards the ventral mar-



Plate 11. Figures 58–62. *Cymbella heterogibbosa* H.Kobayasi & Mayama. LM. Size diminution series, valve views. Scale bar = 10 μm .

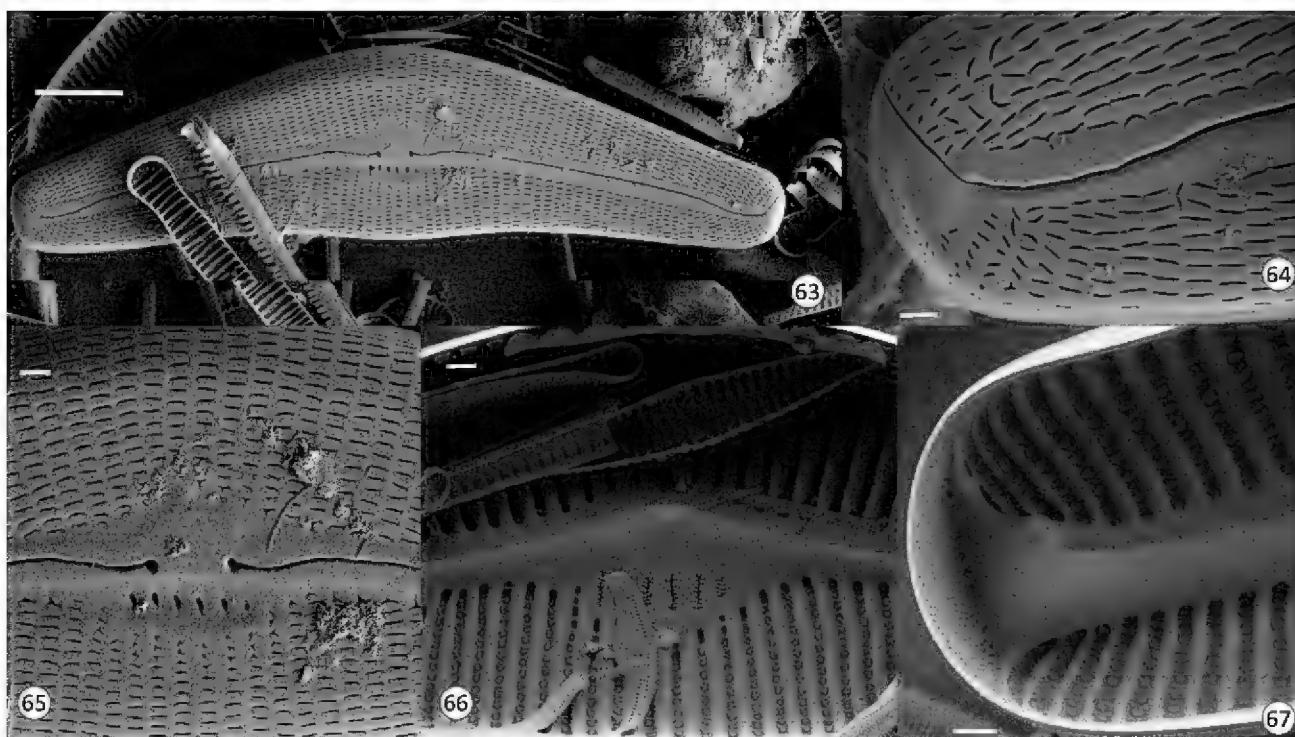


Plate 12. Figures 63–67. *Cymbella heterogibbosa* H.Kobayasi & Mayama. SEM. Figs 63–65, external views. Fig. 63. Whole valve. Scale bar = 10 μm . Fig. 64. Apex, showing apical pore field porelli located on the valve mantle. The distal raphe end is deflected towards the dorsal margin. Scale bar = 1 μm . Fig. 65. The central portion of the valve with dilated proximal raphe ends, slit-like areolar openings and isolated stigmata evident. Scale bar = 1 μm . Figs 66, 67, internal views. Fig. 66. The central portion of the valve showing slide-like stigma openings with small projections. The areolae have C-shaped occlusions. Scale bar = 1 μm . Fig. 67. The apex of the valve with axial area extending beyond helictoglossa. The porelli of the apical pore fields are positioned on the mantle only. The areolae have C-shaped occlusions. Scale bar = 1 μm .

gin. External distal raphe ends are strongly curved towards the dorsal margin, and do not bisect the distinct terminal apical pore fields. Stigmata are positioned on the ventral side of the central area, 3–5 in number. Striae are distinctly punctate, radiate, 12–14 / 10 μm . A hooded structure (the continuous internal proximal raphe ends) occurs on the dorsal side of the central area.

In the SEM, the valve exterior is dominated by lineolate striae (Figures 63–65). The raphe is undulate, with proximal ends dilated. Stigma openings are ellipsoidal in shape (Figures 63, 65). The apices show the distal raphe ends deflected towards the dorsal margin. There is a hyaline area beyond the raphe (Figure 64). The apical pore field is positioned well onto the valve mantle. Internally, the raphe appears to lack an intermissio, and the stigma openings are slit-like with small, stub-like projections on either side (Figure 66). Areolae appear to be occluded internally (Figure 66). At the apices, the helictoglossae are large, bent to one side, and have a transversely thickened area. The apical pore field porelli are visible beyond the helictoglossae on the valve mantle (Figure 67).

Comments: The valves of this species from Torch Lake are slightly larger than those reported by Patrick and Reimer (1975) as *Cymbella cistula* var. *gibbosa* Brun, from Lake Michigan. Krammer (2002) investigated *C. cistula* var. *gibbosa*, and determined it to be less similar to *C. cistula* than to a new species he described, *C. neocistula*. Krammer (2002, p. 95) recognized it at the infraspecific level as *C. neocistula* var. *islandica* Krammer, a name recognized by Bahls (2016) in his treatment of this taxon, also reporting it from Montana. At the species level this diatom was given the new combination *C. gibbosa* (Brun) F.Meister 1912, which is a later homonym of *C. gibbosa* Pantocsek 1902. Mayama et al. (2002) recognized this taxon at the species level and provided the new name *Cymbella heterogibbosa* H. Kobayasi & Mayama. Krammer (2002, p. 95) noted that var. *islandica* “is a connecting link between *C. neocistula* and *C. dorsonotata* [Østrup].” Krammer did not provide illustrations of the ultrastructure of *C. dorsonotata*, nor did he elaborate on the nature of this “connecting link.”

While there are ultrastructural similarities between the nominate variety of Krammer’s *C. neocistula* and *C. neocistula* var. *islandica*, in particular in the structure of the wide internal hyaline area connected to the helictoglossa, the stigmata, and the areolae, there are differences also, especially in the degree of deflection of the external proximal raphe ends, and in the structure and position of the apical pore fields. Hence, we prefer to recognize this taxon at the level of species. Reports of dorsally placed isolated stigmata (Patrick & Reimer 1975) could not be verified in the Torch Lake or other specimens from Iceland (Krammer 2002) or Montana (Bahls 2016).

Cymbella torchiana Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek, n. sp. (Figures 68–75).

Description: Valves are distinctly asymmetrical to the apical axis. The dorsal margin is highly convex, while the ventral margin is straight with a distinct tumid area in the center. Valve apices are barely protracted and they are rounded. Valve length is 26–49 μm and breadth is 7–9 μm . The narrow axial

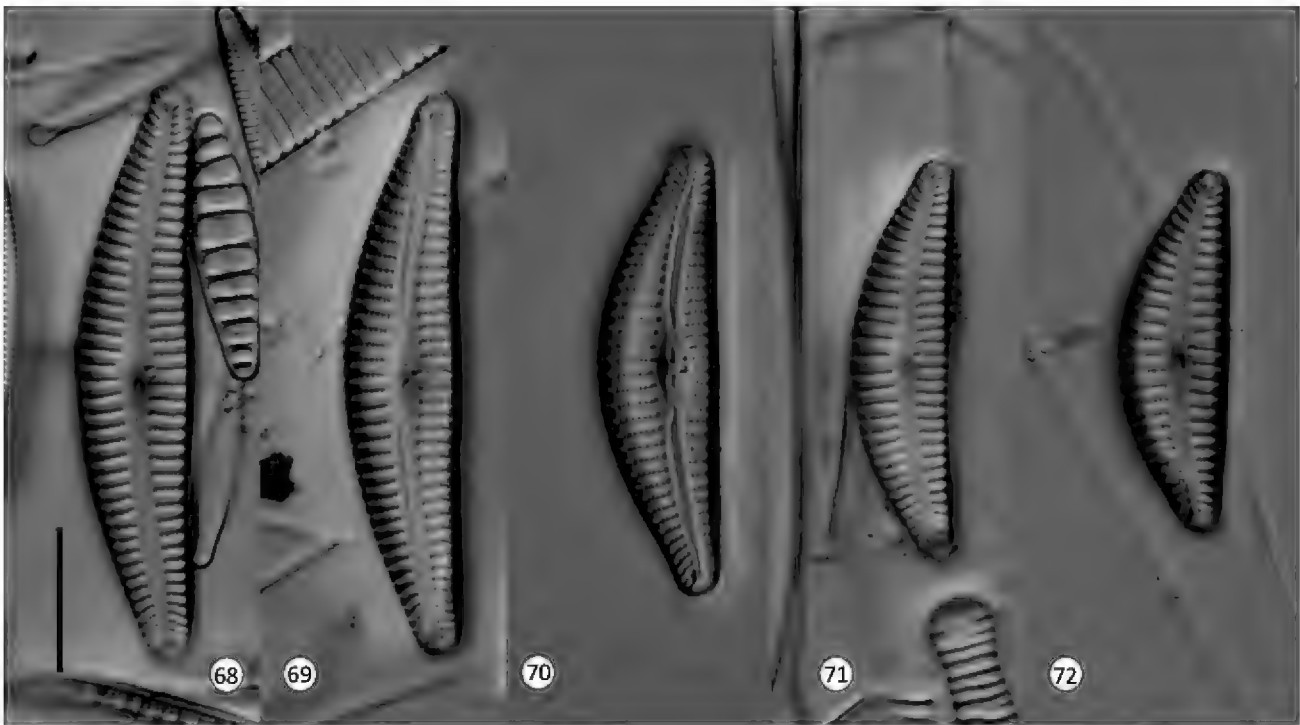


Plate 13. Figures 68–72. *Cymbella torchiana* Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek. LM. Size diminution series, valve views. Fig. 69 is of the holotype. Scale bar = 10 μ m.

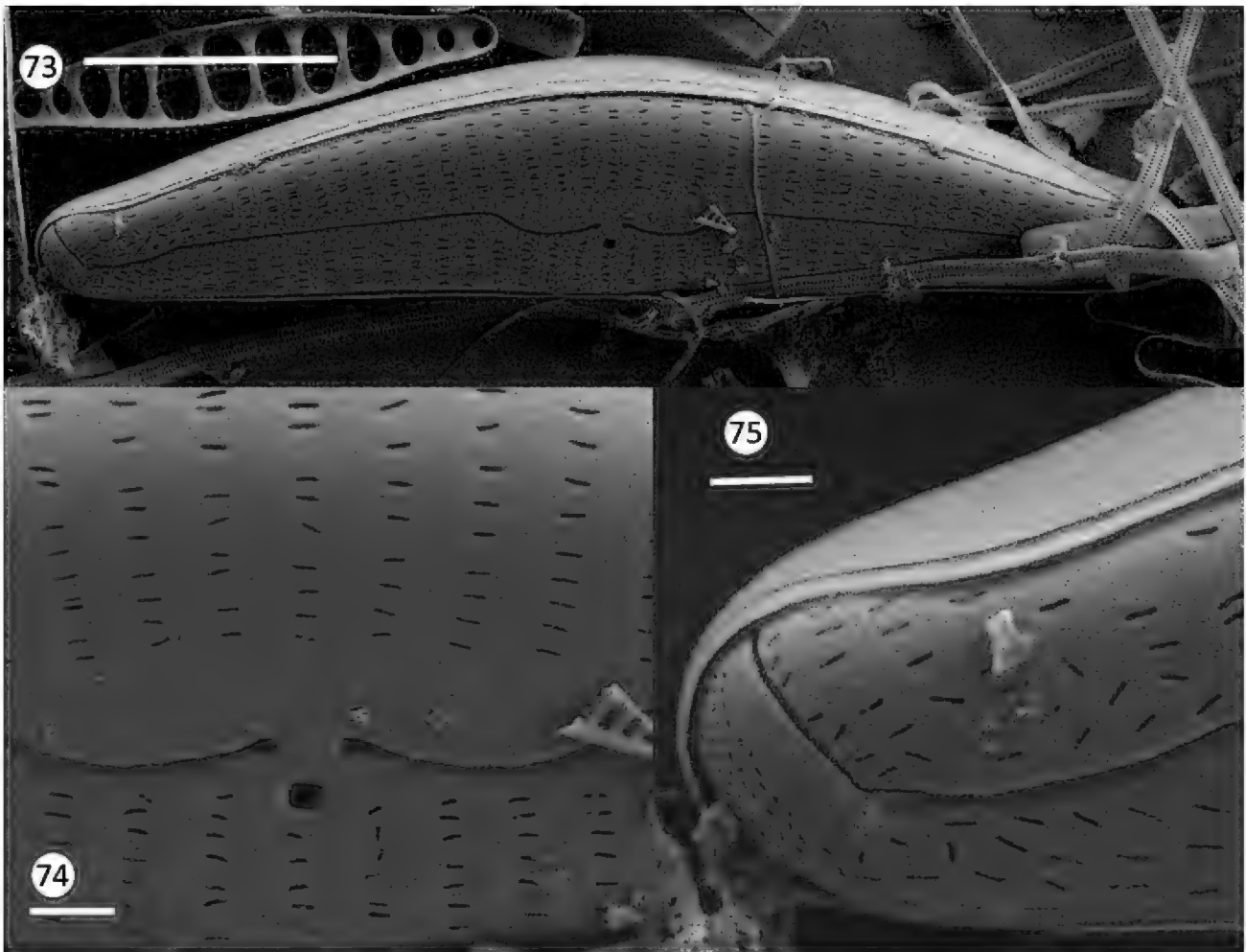


Plate 14. Figures-73–75. *Cymbella torchiana* Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek. SEM, external views. Fig. 73. Entire valve showing undulate raphe, large stigma opening, and dash-like openings of the areolae. Scale bar = 10 μ m. Fig. 74. The central portion of the valve with proximal raphe ends and stigma opening evident. Scale bar = 1 μ m. Fig. 75. The apex of the valve with the porelli of the apical pore field appearing small and round as compared to the slit-like areolae. The striae and pore field are separated by distal raphe end. Scale bar = 1 μ m.

area is arched to the contour of the valve. The axial area is more or less placed centrally and it lacks a distinct central area. The raphe is lateral but becomes reverse-lateral near the center. The external distal ends are deflected dorsally. A distinct, single stigma is present in the center of the valve on the ventral side. Striae are distinctly punctate. The striae are radiate on the dorsal margin, radiate at the center, then become convergent then radiate at the ends on the ventral margin. Striae number 10–12 / 10 μm . Apical pore fields are evident at the poles.

In the SEM, the valve exterior shows an undulate raphe system (Figure 73), with the proximal ends dilated slightly and the distal ends deflected strongly to the dorsal margin (Figure 74). Striae are comprised of slit- or dash-like openings, with inconsistent spacing of areolae within the striae. In the central area, the stigma opening is prominent and round, positioned just ventral to the proximal raphe ends (Figure 74). At the apices, the apical pore fields are positioned at the terminus on the mantle and towards the ventral margin (Figure 75).

Holotype: Slide 650058 deposited at COLO

Isotype: Slide GC59345 deposited at ANSP.

Comments: The outline of the valve, which has blunter apices where the apical pore fields are evident, in contrast to Reimer's interpretation of the lectotype of *C. cymbiformis* Agardh (Patrick and Reimer 1975, plate 10, figure 3). The single enlarged stigma is distinctive in this species. Our new species is much smaller and narrower than *C. cymbiformis*, as interpreted by Krammer (2002), and closely resembles *C. simonsenii* Krammer, differing in being smaller, more finely striated, and having a distinct tumid ventral margin. The Torch Lake specimens correspond well to those labeled "*Cymbella nov. spec.* Nr. 6 Mittersee" and "*Cymbella affinis* Morphotype II" in Lange-Bertalot & Metzeltin (1996, plate 91, figures 10–12 and figures 8 and 9, respectively).

Etymology: Named for the lake in which it was discovered.

Epithemia antrimiana Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek, n. sp. (Figures 76–79).

Description: Valves are strongly asymmetrical to the apical axis. The dorsal margin is highly convex and the ventral margin is nearly straight to slightly concave. The apices are protracted, and are rounded to slightly truncate. Valve length is 95–150 μm and breadth is 26–29 μm . The raphe is evident along the ventral margin at the apices and biarcuate in shape. They extend from the ventral margin and curve towards the dorsal margin. Costae are robust, 2–4 / 10 μm . The striae are coarse, 7–10 / 10 μm .

Holotype: Slide 650056 deposited at COLO.

Isotype: Slide GC59346 deposited at ANSP.

Etymology: Named for Antrim County, in which Torch Lake is located.

Comments: We believe Patrick and Reimer's (1975) report of *Epithemia smithii* Carruthers from nearby Lake Michigan is incorrect. The dimensions listed by them (length 30–73 μm , breadth 9–18 μm) and by Krammer and

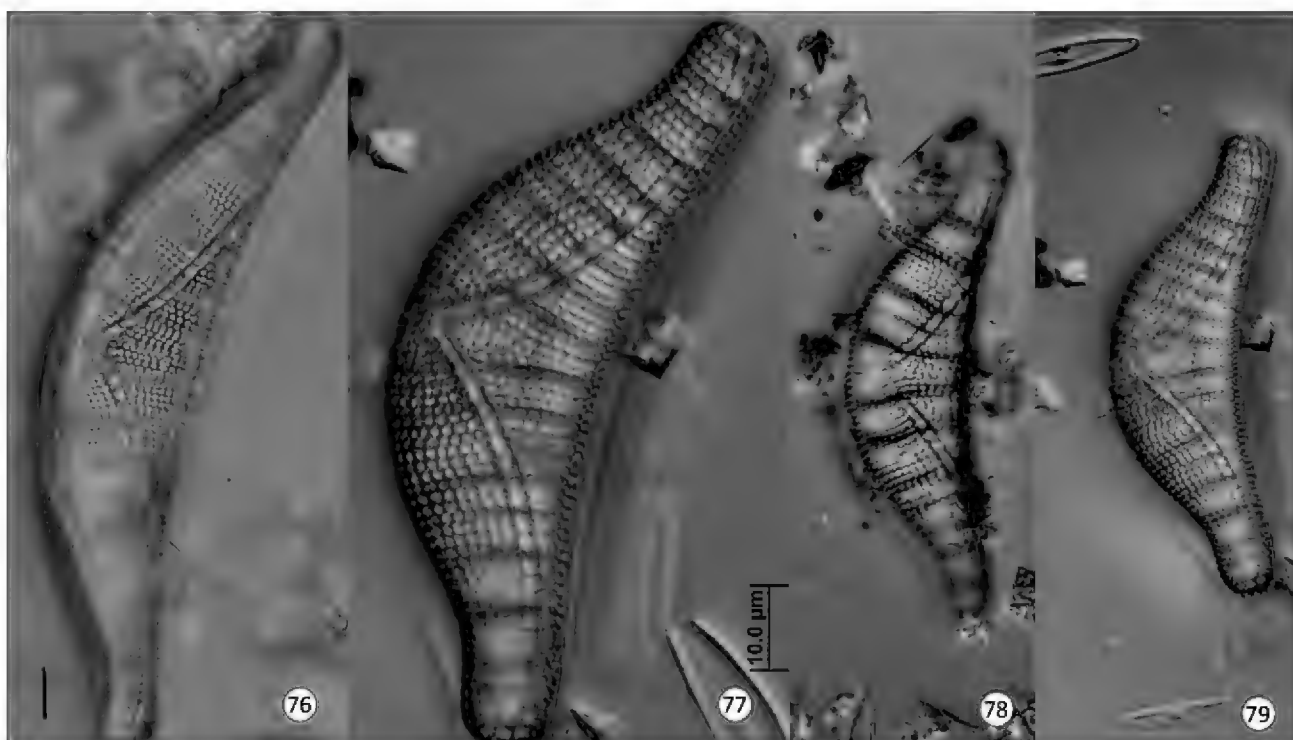


Plate 15. Figures 76–79. *Epithemia antrimiana* Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek. LM. Size diminution series, valve views. Fig. 77 is of the holotype. Scale bar = 10 μm .

Lange-Bertalot (1988) for the same taxon (length 28–80 μm , breadth 9–18 μm) refer to a much smaller diatom than *E. smithii*. We therefore propose a new species to recognize this much larger form.

Nitzschia michiganiana Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek, n. sp. (Figures 80–94).

Description: Valves are linear and have nearly parallel margins. Each margin may be slightly constricted in the middle or this may be evident on one side only or absent. The margins then taper to narrow, blunt ends. Valve length is 35–83 μm , breadth is 6–8 μm . There is the appearance of a slight undulation of the valve face near the raphe-bearing side of the valve face. A central nodule is absent. The raphe is indistinct. The fibulae are small, indistinct and aligned with the striae. The striae are distinctly punctate, parallel in their orientation and have a density of 13–16 / 10 μm . The areolae number 35–37 / 10 μm .

In the SEM, the valve exterior has a keel on one margin of the valve, and a perpendicular wing elevated on the other margin (Figure 86). The striae are uniseriate with external occlusions, except those bordering the keel, where single rows of areolae give way to double rows of smaller areolae (Figures 86–88). The distal raphe ends are deflected away from the valve face (Figure 88). The wing is narrow and can be buttressed with extensions from the valve mantle (Figures 89, 90). Internally, uniseriate striae extend across the valve face (Figures 91, 92). Narrow fibulae extend across the canal raphe (Figure 92). The fibulae may be straight, crooked, or bifurcating (Figures 91–93).

Comments: The densities of striae and areolae are greater than reported for *Nitzschia brunoii* Lange-Bertalot (Lange-Bertalot and Metzeltin 1996), the most

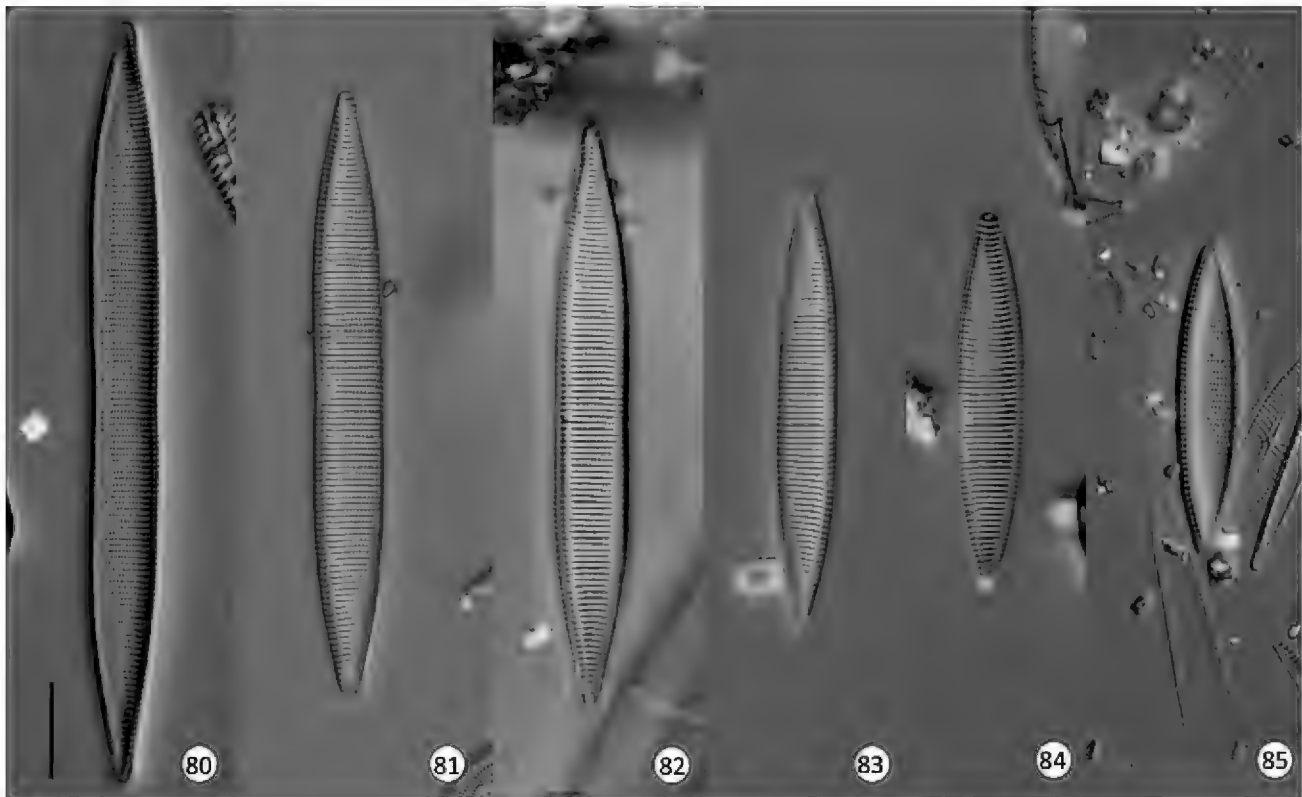


Plate 16. Figures 80–85. *Nitzschia michiganiana* Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek. LM. Size diminution series, valve views. Fig. 81 is of the holotype. Scale bar = 10 μ m.

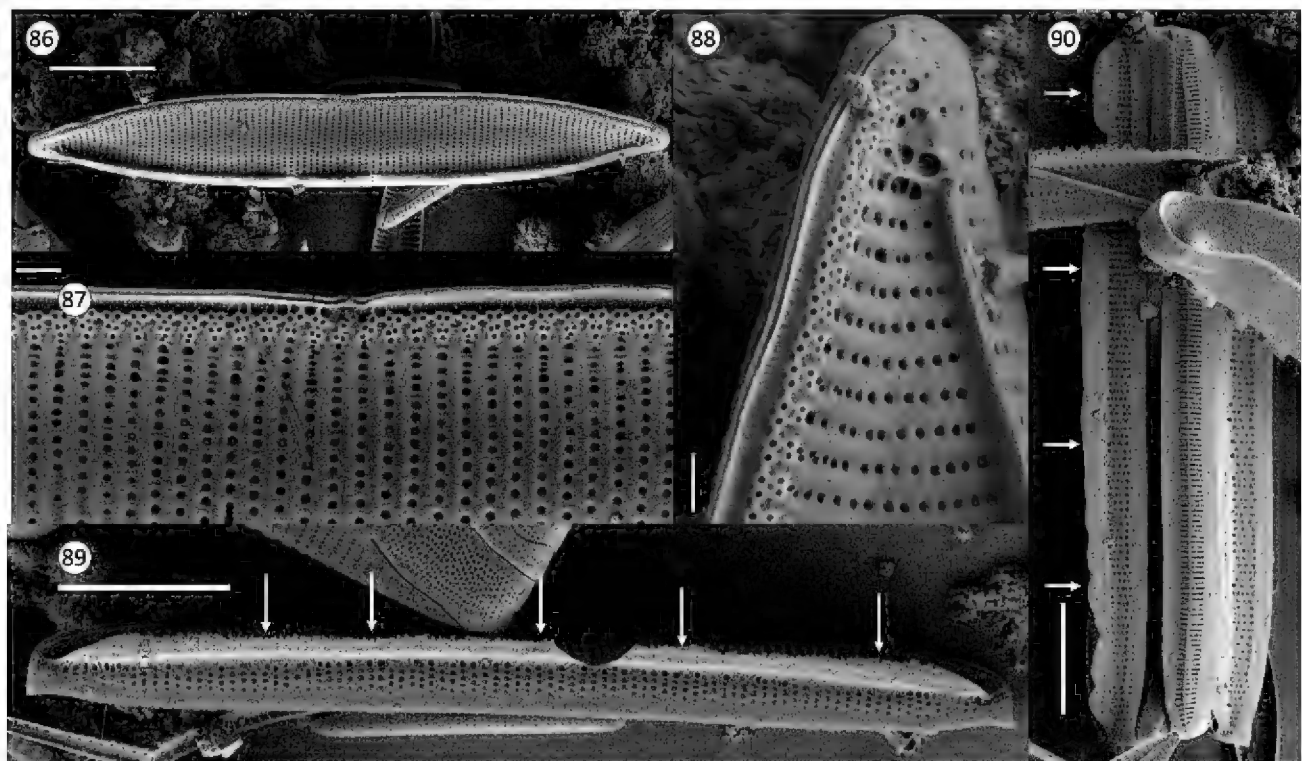


Plate 17. Figures 86–90. *Nitzschia michiganiana* Kociolek—. SEM, external views. Fig. 86. Valve view with uniseriate rows of round areolae comprising the striae. Scale bar = 10 μ m. Fig. 87. View of the central portion of the valve at the raphe. The proximal raphe ends are evident, and the raphe is in a narrow keel. There are 3 rows of smaller areolae, mostly in double rows, next to the keel. Scale bar = 1 μ m. Fig. 88. The apex of the valve. The raphe is seen in a keep on one side of the valve, and a silica extension is seen on the other side. Scale bar = 1 μ m. Figs 89, 90. Girdle views showing the silica extension (arrows) from the non-keeling-bearing side of the valve. Scale bars = 10 μ m.

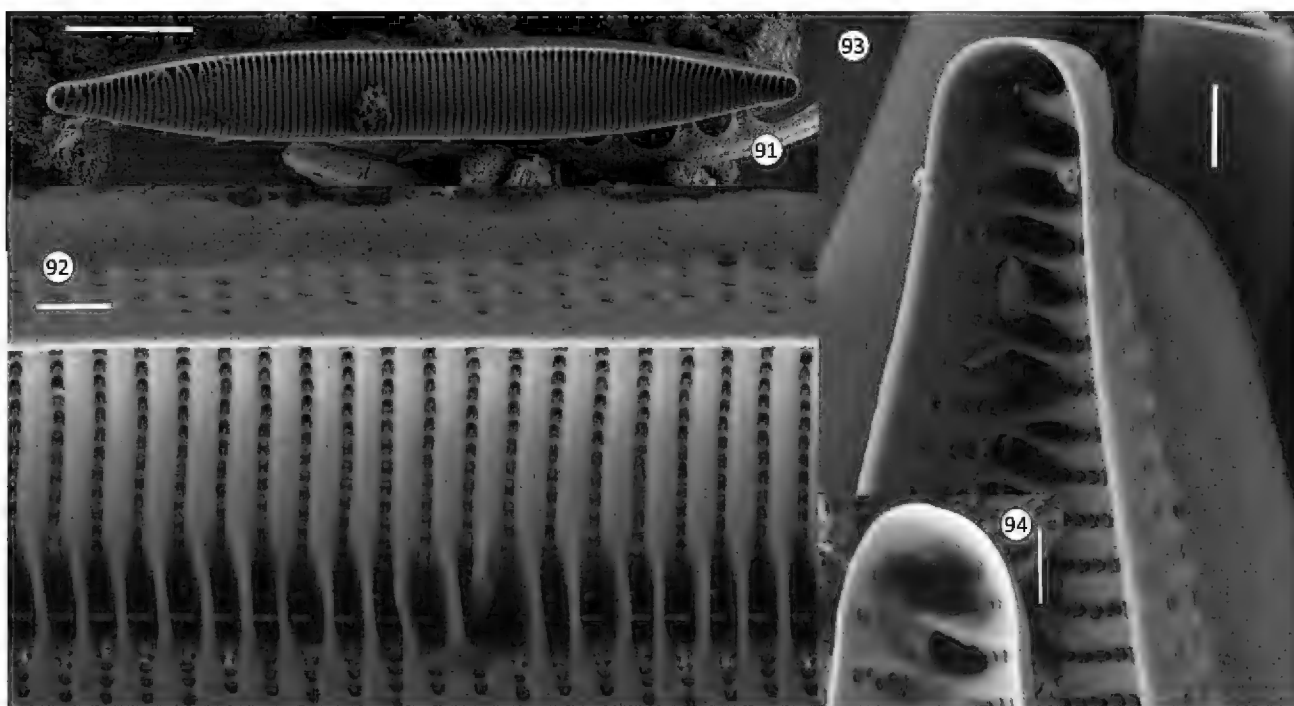


Plate 18. Figures 91–94. *Nitzschia michiganiana* Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek. SEM, internal views. Fig. 91. Whole valve view. Scale bar = 10 μm . Fig. 92. View into the raphe canal. The fibulae are wider on either side and narrower across the opening. The striae are distinctly uniseriate. Scale bar = 1 μm . Figs 93, 94. The apices of the valve. Scale bars = 1 μm , respectively.

morphologically similar species. Lange-Bertalot and Metzeltin (1996) indicate that there is an indistinct undulation on the valve face and suggested that *N. bruno*i might be better placed in the genus *Tryblionella* than in *Nitzschia*. The appearance of an undulation in *Nitzschia michiganiana* is actually a narrow wing of silica opposite the side of the keel and projecting perpendicular to the plane of the valve face. The new species differs from species of *Tryblionella* by lacking an undulation on the valve face, a diagnostic feature of that genus (Round et al. 1990; Cavalcante et al. 2013)

Holotype: Slide 650059 deposited at COLO.

Isotype: Slide GC 59347 deposited at ANSP.

Etymology: Named for the state of Michigan.

Cymatopleura narwoldorum Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek, n. sp. (Figures 95–101).

Description: Valves are robust, panduriform and symmetrical to the apical and transapical axes. The valve margins are constricted in the middle. Valves have slightly protracted, acute apices. The valve face has 3–6 transapical undulations. Valve length is 70–102 μm and breadth is 26–31 μm as measured at the constricted section in the middle of the valve. Fibulae number 10–13 / 10 μm . The fibulae are more developed near the margin than on the rest of the valve face. A central line is weakly developed and not necessarily straight. The striae are fine and difficult to observe in LM.

In the SEM (Figures 99–101), the valve interior has fine striae comprised of

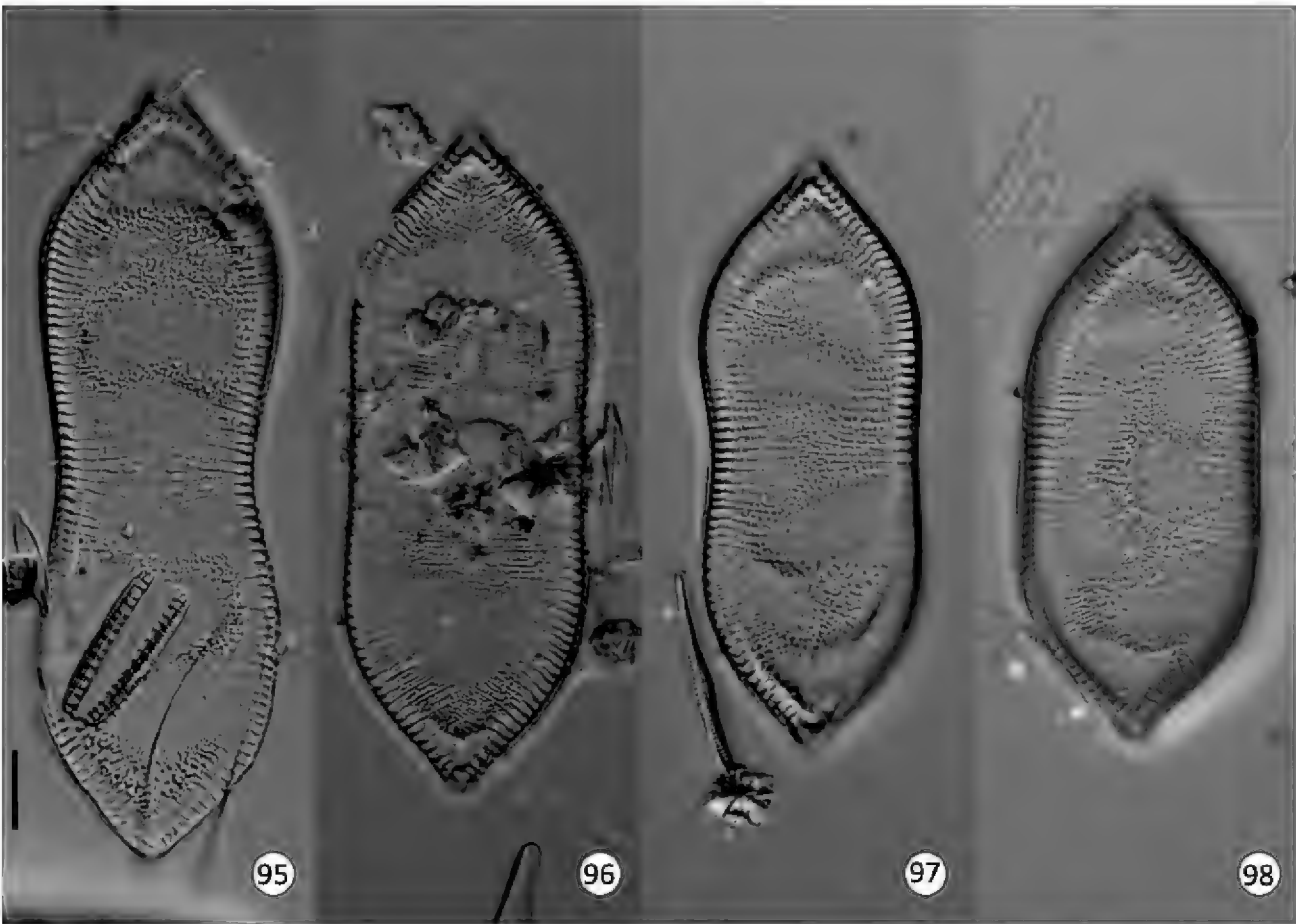


Plate 19. Figures 95–98. *Cymatopleura narwoldorum*, Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek. LM. Size diminution series, valve views. Fig. 97 is of the holotype. Scale bar = 10 μ m.

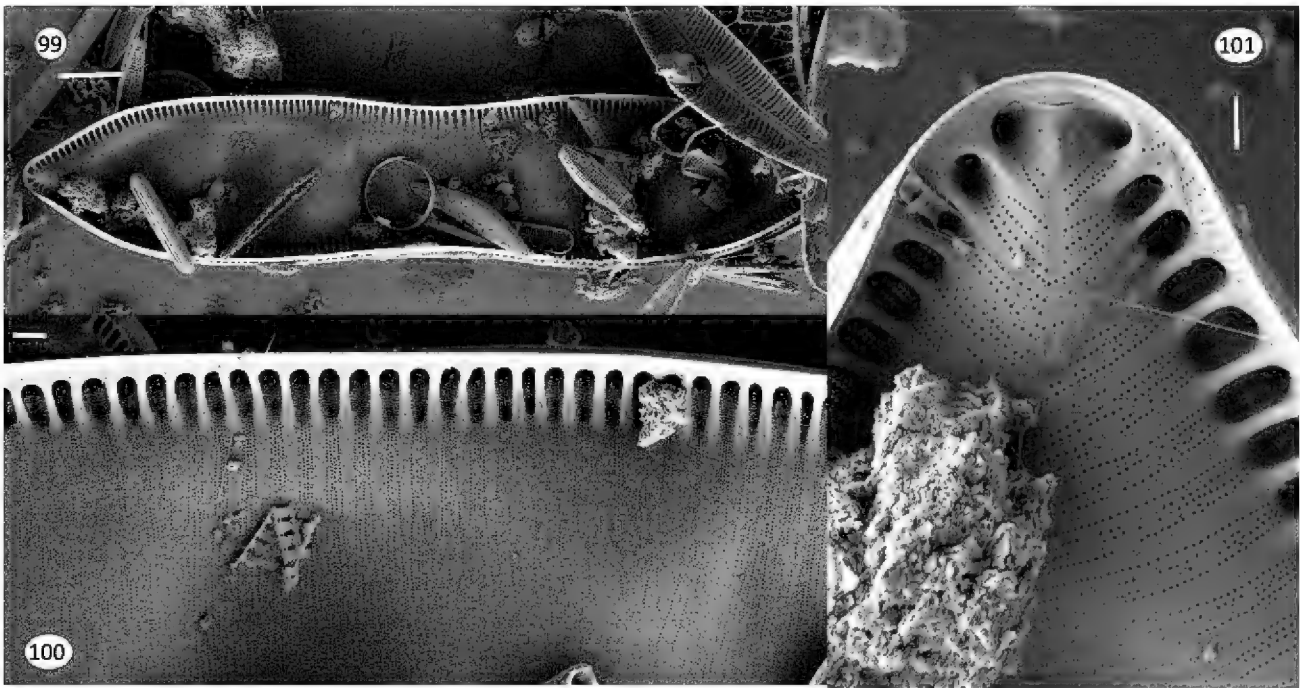


Plate 20. Figures 99–101. *Cymatopleura narwoldorum*, Kociolek, R. L. Lowe, K. Sanchez, & J. G. Stepanek. SEM, internal views. Fig. 99. Entire valve. Scale bar = 10 μ m. Fig. 100. View near the margin at the center of the valve. The striae are uniseriate, occurring in groups of 2 or (mostly) 3 rows. Scale bar = 1 μ m. Fig. 101. The valve apex with the raphe continuous across the terminus. The striae are comprised of small, round areolae. Scale bar = 1 μ m.

mostly uniseriate rows. The striae are 35–50 / 10 μm . The striae extend across the valve face, and beyond the fibulae, where they are organized into groups of 2 or 3 rows (Figures 100, 101). The striae also extend onto the narrow mantle. The fibulae number 10–13 / 10 μm .

Holotype: Slide 650060 deposited at COLO.

Isotype: Slide GC59348 deposited at ANSP.

Comments: This species is similar in the shape of the apices to *C. internationale* Bahls, a species described from Glacier National Park (Bahls 2013). That species, however, has no central constriction, is shorter and wider, and the fibulae are less dense, which makes it easy to distinguish from *C. norwaldorum*.

Etymology: Named for Trish and Andrew Narwold, for their dedication to and appreciation of Torch Lake and for introducing us to this fabulous lake.

DISCUSSION

This preliminary study of the diatom flora of Torch Lake reveals that it contains a significant number of taxa, comparable with other oligotrophic lakes. For example, the 176 taxa recognized here from a few samples taken near the shore of the lake during two sampling periods in a single season are comparable to what is found in alkaline oligotrophic lakes in Europe (e.g., Lange-Bertalot and Metzeltin 1996). In Julma Ölkky, Weinfelder Maar, and Mittersee, three lakes in northern Europe, Lange-Bertalot and Metzeltin (1996) reported 823 diatom taxa based on only a few samples. The species lists from these oligotrophic environments in Europe, especially from Weinfelder Maar, an alkaline lake in Germany, and from Torch Lake in North America are strikingly similar, with many species of cymbelloid diatoms in the lists from both places. The new taxa from these places appear also to have strikingly similar (perhaps sister?) species on the other continent (e.g., *Nitzschia brunoi* versus *N. michiganiana*; *Cymbella torchiana* versus *C. sp. #6* in Lange-Bertalot and Metzeltin 1996). The similarity between the two regions is also demonstrated by the fact that several species reported previously from Europe were documented in Torch Lake as new reports for the United States. Kociolek and Stoermer (2009) suggested that aside from a few studies of some larger lakes and unique habitats (such as aerophilous environments and springs), the proportion of studies in oligotrophic environments versus eutrophic aquatic habitats is quite low, despite oligotrophic habitats harboring many undescribed species and the need to conserve and protect these types of environments. While this preliminary study has documented six new species from Torch Lake, it is evident that additional work will yield other new taxa. Lange-Bertalot and Metzeltin (1996) originally described 55 new species from these three northern European lakes and suggested that 25% of the 823 taxa recorded may be new to science.

Although early studies of diatoms in the Great Lakes region began with Ehrenberg (1854), and the region has been the focus of detailed taxonomic work (e.g., Stoermer and Ladewski 1982; Kociolek and Stoermer 1991) and floristic studies (e.g., Wujek 1967; Millie and Lowe 1981), many parts of the region have

not been adequately sampled or studied. The Laurentian Great Lakes has received significant attention, and taxonomic work on which many ecological studies are based have been forthcoming (e.g., Reavie and Kireta 2015); nevertheless, there is apparently still significant undescribed diversity to uncover and describe.

ACKNOWLEDGMENTS

We thank Trish and Dr. Andrew Narwold, Lyn and Gary Petty, Dr. Becky Norris, Art and Steve Hoadley, Jackie Pilette, and the Freshwater Algae Class of 2014 at the University of Michigan Biological Station for their encouragement, help, and support for this project. This manuscript benefited from helpful reviews by Vivianna Mazzei and an anonymous reviewer, as well as help from Dr. Michael Huft and the editorial office, for which the authors are grateful.

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DISCOVERY OF THE FIRST KNOWN PATTERNED FEN IN MICHIGAN'S LOWER PENINSULA

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ABSTRACT

Patterned fens are peatlands characterized by an alternating series of hummocks and hollows that form perpendicular to the direction of water flow through the peatland. Their characteristic microtopography supports strongly differentiated plant assemblages and forms a ribbed pattern when viewed from above. The hummocks are characterized by mosses and tussock forming vascular plants that support woody vegetation. This contrasts with the relatively low and wet hollows which typically support sedges and aquatic plant species and have high pH relative to neighboring hummocks. Patterned fens are mainly circumboreal in distribution. In the continental United States, patterned fens are known from the northeastern states and the upper Great Lakes region. This paper describes a small patterned fen discovered near Levering, Michigan, the first patterned fen documented in Michigan's Lower Peninsula.

KEYWORDS: patterned fen, patterned peatland, Michigan, strings, flarks

INTRODUCTION

Patterned fens are peatlands characterized by microtopography consisting of an alternating series of semi-linear hummocks and hollows dubbed "strings" and "flarks," respectively. The characteristic patterning forms such that the features are oriented perpendicular to the flow of water. The hummocks, which give strings their slightly elevated microtopography, are generally composed of mosses, often *Sphagnum* spp., and tussock forming vascular plant species such as *Carex exilis* Dewey. The raised position relative to the water table allows strings to support a range of woody species from shrubs to stunted trees, among which ericaceous shrubs and conifers are prevalent. Conversely, flarks are low and wet, support few or no woody species, and often contain open water which supports submergent species such as *Utricularia* spp. (Vitt et al. 1975; Glaser et al. 1981; Foster and King 1984; Madsen 1987; Glaser 1992a; Graeff 2018). The pH of patterned fens varies considerably within and among them, ranging broadly from acidic to alkaline. Strings tend to be more acidic than flarks (Heinselman 1970, Glaser et al. 1981, Foster and King 1984, Sjörs and Gunnarsson 2002, Slaughter and Cohen 2010, Graeff 2018). Variability in

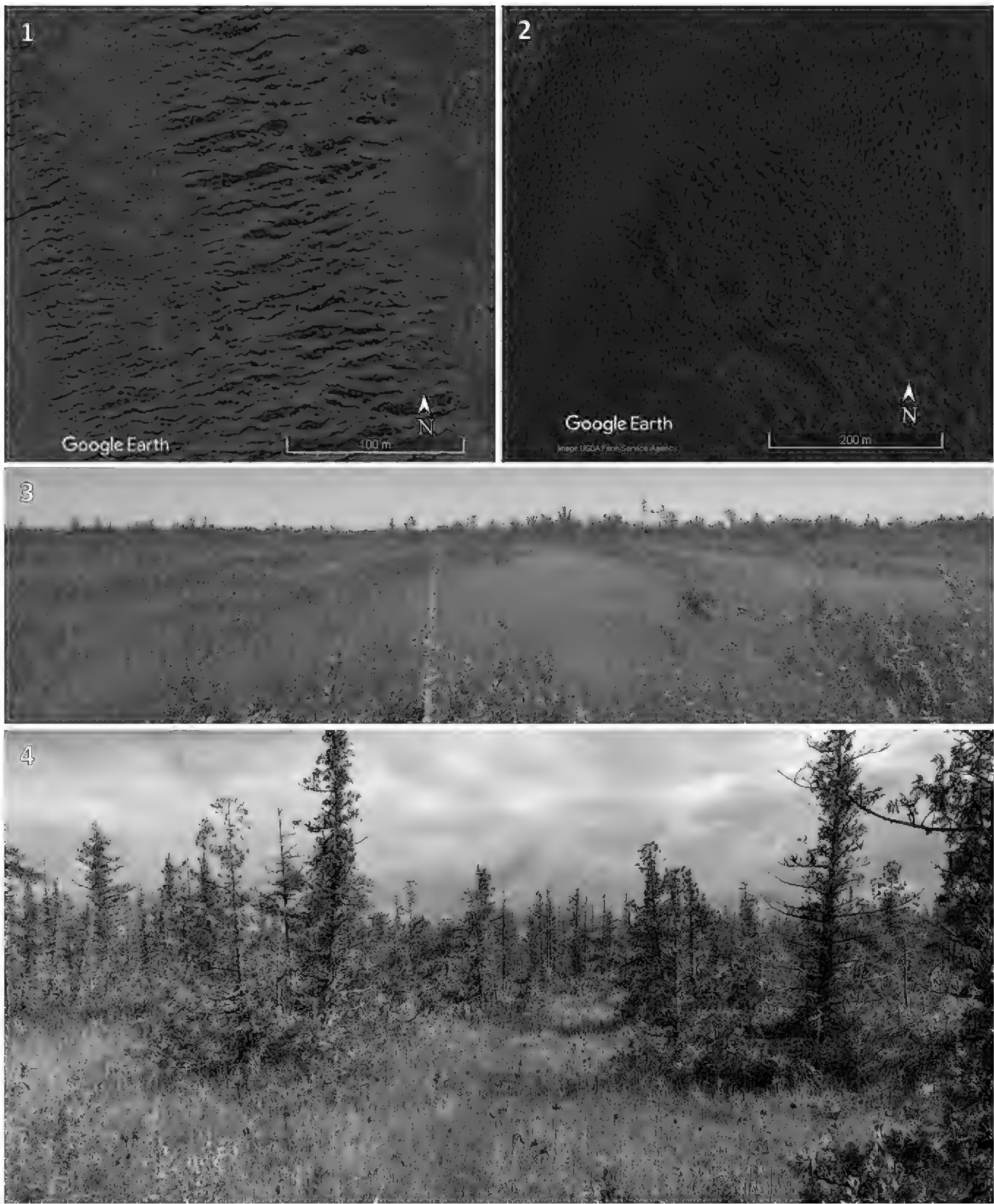


FIGURE 1. Examples of patterned fen microtopography as seen from aerial imagery and at ground level at Seney National Wildlife Refuge, Michigan: (1) aerial image, May 8, 2016; and (3), ground level photo, July 21, 2016; and near Calumet, Michigan: (2), aerial image, August 27, 2005; and (4) ground level photo, August 29, 2020. Note the differences in linearity and vegetation: the strings are low and shrubby but fairly linear at Seney, whereas at Calumet they are less organized in pattern but support stunted trees and are thereby vertically exaggerated. Aerial imagery from Google Earth, accessed December 14, 2020. Image (1) from Landsat/Copernicus; image (2) from USDA Farm Service Agency. Photos by Alex Graeff.

relative height, length, width, and vegetation of strings and flarks contribute to a diverse range of patterning (Figure 1) (see Slaughter and Cohen 2010 for additional photos of different patterns in Michigan). Some of the faintest patterning is most easily seen on aerial imagery but can usually also be discerned on the ground.

Patterned fens and other peatlands are found where excess moisture is abundant (i.e., where precipitation is greater than evapotranspiration) (Boelter and Verry 1977; Gignac et al. 2000; Halsey et al. 2000). Patterned fens are mainly circumboreal in distribution, occurring throughout northern regions of North America and Eurasia, though they also occur sparingly in other regions, such as southern South America and New Zealand (Mark et al. 1995). They are astonishingly abundant in the Hudson Bay lowlands (Sjörs 1959; Riley 2011). In the continental United States, most occurrences are in the Upper Great Lakes region, where they are particularly abundant and extensive in lake plains of glacial Lake Agassiz in northern Minnesota (Albert 1995). Some of the large patterned peatlands in Minnesota, such as those in the Red Lake region, are well-studied (Wright et al. 1992).

In Michigan, patterned fens are found mainly in the eastern Upper Peninsula (UP), where they occur on glacial lake plains and outwash channels particularly of the Seney Sand Lake Plain and Grand Marais Sandy End Moraine and Outwash. Michigan patterned fens are concentrated on poorly-drained lake plains that are former embayments of glacial Lake Algonquin (Albert 1995). Broad expanses of relatively flat, poorly-drained landscapes with highly conductive medium-textured lacustrine sands and sandy glacial outwash underlain by calcareous sedimentary bedrock provide the ideal geological and hydrological setting for their formation (Madsen 1987). However, while most patterned fens in Michigan occur in the relatively narrow region of the eastern UP, and most extensively in large lake plains, they do occur sparingly outside of this region and in much smaller basins (Slaughter and Cohen 2010). Within the UP, there are 22 documented occurrences of patterned fen, totaling 17,323 ha. These occurrences range from 4.4 ha to 8,953 ha and average 788 ha (MNFI 2020). The northern tip of Michigan's Lower Peninsula (LP) shares similar climatic conditions with the eastern UP and contains some large peatlands, though no patterned fens have previously been noted or described from this region. This publication serves to briefly describe the discovery of a small patterned fen found in the LP.

MATERIALS AND METHODS

While exploring aerial imagery to identify landscapes of interest, we identified what looked like a small patterned fen within a large swamp complex near the town of Levering, Michigan (Figure 2). The feature was approximately north of Lost Lake, at the western edge of a large conifer swamp, about 300 m from adjacent uplands. It was approximately 2.5 ha in size, with land ownership split between the Michigan Department of Natural Resources and a private owner.

The Lost Lake swamp complex lies in the western portion of sub-subsection VII.6.1 (Onaway) of the Regional Landscape Ecosystems of Michigan classification which contains large expanses of lake plain. Some of these are poorly drained and support various wetlands (Albert 1995). The post-

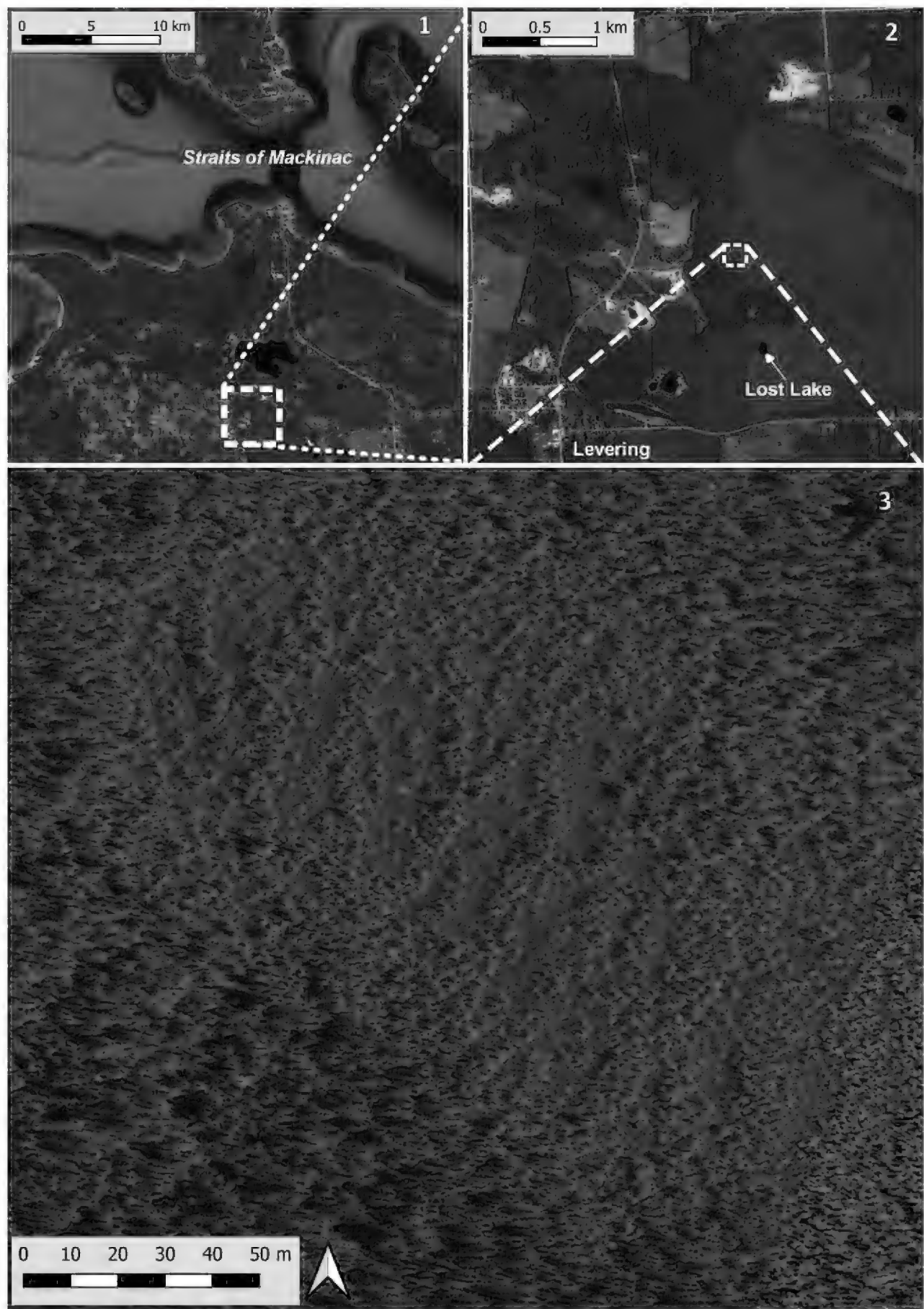


FIGURE 2. Aerial imagery of the Lost Lake patterned fen near the town of Levering at the northern tip of Michigan’s Lower Peninsula. (1) The location of the Lost Lake conifer swamp near the tip of the Lower Peninsula, indicated by the box with dashed borders. (2) The area depicted by the box in image 1; the box indicates the location of the Lost Lake fen. (3) The Lost Lake fen. Imagery from Google Earth, accessed December 20, 2020. Imagery date 30 July 2019. Image (1) from NOAA, © 2020 Google, © 2020 Terrametrics; images (2) and (3) © 2020 Google.

glacial setting of this portion of the sub-subsection is similar to large expanses of glacial plains and channels that support patterned fens in the eastern UP.

Ground visits were made on July 6, 2019 and August 18, 2019, when we collected basic preliminary qualitative data of the peatland's floristic composition. During each visit, we recorded plant species encountered within strings, flarks, and unpatterned portions of the fen. Additional notes about relative abundance of plant species within strata and soil chemistry and characteristics were recorded during the August visit. An Oakfield 36-inch soil auger was used to extract peat cores from the strings and flarks, and a Lovibound soil pH test kit was used to evaluate organic soil pH. Our survey efforts focused on the state-owned portion at the southeast end of the fen.

RESULTS

Ground observations at the Lost Lake Fen revealed peats and plant communities characteristic of patterned fen. We identified string-flark patterning with distinct plant assemblages (Table 1). Some neighboring strings and flarks displayed sharp contrast in plant species assemblages (Figure 3A) while others displayed a pronounced transition zone (Figure 3C) that resembled unpatterned areas of shrub fen. Peats were acidic (pH 4.5) to alkaline (pH 7.5), saturated to inundated, typically ranged from fibric to hemic, and were greater than one meter in depth.

The strings were characterized by an overstory of scattered and stunted conifers, an understory of shrubs, and a hummocky ground layer that supported dwarf shrubs, and various forbs and graminoids (Figure 3; Table 1). Overstory conifers were dominated by *Picea mariana* and *Thuja occidentalis* mixed with *Larix laricina* and *Pinus strobus*, each averaging 1 to 3 meters tall and ranging from 2 to 5 cm DBH. Characteristic understory and low shrubs included *Betula pumila*, *Chamaedaphne calyculata*, *Andromeda polifolia* var. *latifolia*, *Rhododendron groenlandicum*, and *Salix pedicellaris*. The ground layer consisted of hummocks about 0.5 m tall with a mixture of mosses including *Sphagnum* spp., one or more species of *Dicranum*, *Pleurozium schreberi*, and one or more species of *Thuidium*, along with the dwarf shrubs *Vaccinium oxycoccos* and *Rubus pubescens*. Herbaceous plants of the ground layer included *Carex lasiocarpa*, *Fragaria virginiana*, *Solidago rugosa*, *Drosera rotundifolia*, and *Campanula aparinoides* (Table 1). The strings were not continuous ridges; rather narrow wet channels dissected them. Peats within the strings were saturated and quickly transitioned from acidic (pH 4.5) at the tops of the sphagnum hummocks to alkaline (pH 7.3–7.5) along the slopes of the strings.

Flarks were wet pools dominated by graminoids including *Phragmites australis* subsp. *americanus*, *Rhynchospora alba*, *Carex lasiocarpa*, *Carex livida*, *Eleocharis elliptica*, and *Trichophorum alpinum* (Figure 3). Other characteristic species found in these flarks included *Sarracenia purpurea* subsp. *purpurea*, *Menyanthes trifoliata*, *Solidago uliginosa*, *Drosera rotundifolia*, and *Utricularia* spp. (Table 1). *Betula pumila* occurred locally within some flarks and was characteristic of the string–flark transition zone. Other species that characterized this zone include *Calopogon tuberosus* and *Valeriana uliginosa*. Peats within the flarks were loose unconsolidated fibric peats that were inundated to super saturated and alkaline (pH 7.3–7.5).

TABLE 1. All plant species observed at the Lost Lake patterned fen on July 6, 2019 and August 18, 2019, sorted by stratum and vegetation zone. Abundance indicates the relative abundance, if noted, of each species within each stratum (D = dominant, C = common, LC = locally common, O = occasional, U = uncommon). Nomenclature follows Voss and Reznicek (2012) for vascular plants and Flora of North America Editorial Committee (1993+) for mosses.

Abundance	Scientific Name
String	
Overstory	
C	<i>Larix laricina</i> (Du Roi) K. Koch
C	<i>Picea mariana</i> (Mill.) Britton, Sterns & Poggenb.
U	<i>Pinus strobus</i> L.
D	<i>Thuja occidentalis</i> L.
Understory	
D	<i>Betula pumila</i> L.
C	<i>Larix laricina</i> (Du Roi) K. Koch
C	<i>Picea mariana</i> (Mill.) Britton, Sterns & Poggenb.
C	<i>Thuja occidentalis</i> L.
Low Shrub	
C	<i>Rhamnus alnifolia</i> L'Hér.
C	<i>Andromeda glaucophylla</i> Link
C	<i>Betula pumila</i> L.
LC	<i>Chamaedaphne calyculata</i> (L.) Moench
C	<i>Larix laricina</i> (Du Roi) K. Koch
U	<i>Pinus strobus</i> L.
C	<i>Rhododendron groenlandicum</i> (Oeder) K.A. Kron & W.S. Judd
C	<i>Salix pedicellaris</i> Pursh
	<i>Lonicera oblongifolia</i> (Goldie) Hook.
	<i>Shepherdia canadensis</i> (L. Nutt)
Ground Cover	
	<i>Campanula aparinoides</i> Pursh
	<i>Carex diandra</i> Schrank
	<i>Carex interior</i> L. H. Bailey
C	<i>Carex lasiocarpa</i> Ehrh.
	<i>Carex leptalea</i> Wahlenb.
	<i>Carex tenuiflora</i> Wahlenb.
	<i>Drosera rotundifolia</i> L.
	<i>Dicranum</i> (Hedwig)
	<i>Eutrochium maculatum</i> (L.) E. E. Lamont
C	<i>Fragaria virginiana</i> Mill.
	<i>Menyanthes trifoliata</i> L.
U	<i>Platanthera lacera</i> (Michx.) G. Don
	<i>Pleurozium schreberi</i> (Willdenow ex Bridel) Mitten
C	<i>Rubus pubescens</i> Raf.
LC	<i>Solidago rugosa</i> Mill.
	<i>Solidago uliginosa</i> Nutt.
C	<i>Sphagnum</i> spp.
	<i>Symphyotrichum boreale</i> (Torr. & A. Gray) Á. Löve & D. Löve
	<i>Thuidium</i> Schimper
	<i>Trichophorum alpinum</i> (L.) Pers.
	<i>Typha latifolia</i> L.
C	<i>Vaccinium oxycoccos</i> L.
Flark	
Ground Cover	
	<i>Carex chordorrhiza</i> Ehrh. ex L. f.
LC	<i>Carex flava</i> L.

(Continued on next page)

TABLE 1. (Continued)

Abundance	Scientific Name
Flark	
Ground Cover	
LC	<i>Carex lasiocarpa</i> Ehrh.
	<i>Carex limosa</i> L.
LC	<i>Carex livida</i> (Wahlenb.) Willd.
	<i>Comarum palustre</i> L.
LC	<i>Drosera rotundifolia</i> L.
LC	<i>Eleocharis elliptica</i> Kunth
	<i>Eriophorum angustifolium</i> Honck.
	<i>Eriophorum virginicum</i> L.
C	<i>Eutrochium maculatum</i> (L.) E. E. Lamont
U	<i>Liparis loeselii</i> (L.) Rich.
C	<i>Lobelia kalmii</i> L.
C	<i>Menyanthes trifoliata</i> L.
LC	<i>Phragmites australis</i> subsp. <i>americanus</i> Saltonstall, P. M. Peterson & Soreng
U	<i>Platanthera lacera</i> (Michx.) G. Don
LC	<i>Rhynchospora alba</i> (L.) Vahl
C	<i>Sarracenia purpurea</i> subsp. <i>purpurea</i> L.
C	<i>Solidago uliginosa</i> Nutt.
U	<i>Trichophorum alpinum</i> (L.) Pers.
U	<i>Utricularia cornuta</i> Michx.
	<i>Utricularia intermedia</i> Hayne
Low Shrub	
	<i>Andromeda glaucophylla</i> Link
U	<i>Betula pumila</i> L.
Shrub Fen	
U	<i>Calopogon tuberosus</i> (L.) Britton, Sterns & Poggenb.
LC	<i>Comarum palustre</i> L.
LC	<i>Cornus sericea</i> L.
O	<i>Drosera rotundifolia</i> L.
U	<i>Geum rivale</i> L.
LC	<i>Lonicera oblongifolia</i> (Goldie) Hook.
LC	<i>Lycopus uniflorus</i> Michx.
O	<i>Muhlenbergia glomerata</i> (Willd.) Trin.
U	<i>Pogonia ophioglossoides</i> (L.) Ker Gawl.
LC	<i>Symphyotrichum boreale</i> (Torr. & A. Gray) Á. Löve & D. Löve
LC	<i>Thelypteris palustris</i> Schott
O	<i>Valeriana uliginosa</i> (Torr. & A. Gray) Rydb.

Areas of shrub fen, which flanked the patterned fen, were characterized by a scattered coniferous canopy with *Thuja occidentalis*, *Picea mariana*, and *Larix laricina*. These conifers were also prevalent in the understory. The low shrub zone was patchy to dense with prevalent species including *Chamaedaphne calyculata*, *Betula pumila*, *Andromeda polifolia* var. *latifolia*, *Lonicera oblongifolia*, and *Cornus sericea*. Prevalent ground cover species included *Sphagnum* spp., *Carex lasiocarpa*, *Rhynchospora alba*, *Vaccinium oxycoccos*, *Rubus pubescens*, *Thelypteris palustris*, and others (Table 1). Peats were saturated, fibric-hemic, and circumneutral to alkaline (pH 7.0–7.5). Vegetation in areas of shrub fen resembled that of the string-flark transition zone.



FIGURE 3. Photos of the Lost Lake Fen. (A) A flark flanked by strings on either side; photo by Joshua Cohen, August 18, 2019. (B) Vegetation within a string. (C) A particularly pronounced transition zone between string (right), and flark (left) with abundant *Betula pumila*. Photos B and C by Alex Graeff, July 6, 2019.

DISCUSSION

The Lost Lake Fen (latitude 45.646°N) lies near the southern limit of most patterned fens in the Great Lakes Region, though two patterned fens are known to occur further south in this region. In Menominee County, Michigan, the Hanson Lake patterned fen lies near 45.315° N latitude. In Wisconsin, the Cedarburg Bog patterned fen is strikingly farther south at about 43.380° N latitude (Grittinger 1970). Using aerial imagery we have observed several patterned fens in the northeastern states that occur farther south than the Lost Lake Fen (see also Almquist and Calhoun 2003; Nichols and Sperduto 2012), though the Cedarburg Bog fen in Wisconsin, to our knowledge, is the farthest south in the continental US.

String and flark species assemblages of the Lost Lake Fen were distinct from each other, and each displayed species typical of those assemblages in other patterned fens in the region. The most obvious difference in string and flark assemblages in the Lost Lake Fen was the presence of overstory and understory strata predominantly of *Picea mariana*, *Thuja occidentalis*, and *Larix laricina* in strings; flarks lacked overstory and understory strata and did not contain conifers. Coniferous species are characteristic of strings in some regional fens but not in others. For example, Madsen's (1987) study of two fens in Michigan's UP noted *Thuja occidentalis*, *Pinus strobus*, *Picea mariana*, and *Larix laricina* as string species in the Shingleton Fen but not in the Creighton Marsh fen. Common or locally common sedges in the Lost Lake Fen flarks such as *Carex livida*, *Eleocharis elliptica*, and *Rhynchospora alba* were characteristic of flarks in the Seney patterned fen (Graeff 2018) and were noted in flarks in both the Creighton Marsh fen and Shingleton Fen (Madsen 1987). In the Lost Lake Fen, the common flark sedges contrast sharply with the string assemblage in which they were not observed.

While the vegetation of the Lost Lake Fen bore similarity to other regional patterned fens, it lacked some typical patterned fen species, highlighting the variability of plant assemblages within the characteristic landforms of patterned fen landscapes. For example, *Carex exilis* is a major hummock-former of strings and is also frequent in flarks and areas of poor fen in some patterned fens, but this species was absent from the Lost Lake Fen. While the presence of *Thuja occidentalis* in strings indicates strong minerotrophic groundwater influence, other such indicators, such as *Hypericum kalmianum* L. and *Dasiphora fruticosa* (L.) Rydb. were not present. Typical flark species such as *Dulichium arundinaceum* (L.) Britton, *Rhynchospora fusca* (L.) W. T. Aitone, *Drosera intermedia* Hayne, *Juncus canadensis* Laharpe, and *Equisetum fluviatile* L. were not noted in the Lost Lake Fen. *Nymphaea odorata* Aiton and *Nuphar variegata* Durand are often present in deeper pools of patterned peatlands, but such pools, and thus these species, were absent. Additionally, many shrub species characteristic of patterned fens were not observed at the Lost Lake Fen. These include *Alnus incana* (L.) Moench subsp. *rugosa* (Du Roi) Clausen, *Aronia prunifolia* (Marshall) Rehder, *Ilex verticillata* (L.) A. Gray, *I. mucronata* (L.) M.Powell, Savol., & S.Andrews, *Kalmia polifolia* Wangenh., *Vaccinium angustifolium* Aiton, *V. myr-*

tilloides Michx, and *V. macrocarpon* Aiton (Glaser et al. 1981; Madsen 1987; Kost et al. 2007; Slaughter and Cohen 2010; Graeff 2018). Such species absences are perhaps related to the small size of Lost Lake Fen and its lack of broader zonation that is characteristic of larger patterned fens. For example, the Lost Lake site does not have expansive areas of poor fen or marginal areas of northern wet meadow. It also lacks fossil dune ridges and their associated upstream ponded areas and downstream forest or shrub swamps such as those that characterize large fens in Michigan's Upper Peninsula (Heinselman 1965; Madsen 1987; Kost et al. 2007; Slaughter and Cohen 2010; Graeff 2018).

The formation of string-flark microtopography in patterned fens has been intensely studied and remains a current topic of investigation. Several mechanisms have been proposed or identified as important in microtopography formation, including peat accumulation, water ponding, nutrient accumulation, frost heaving, and peat slippage (Heinselman 1963; Foster et al. 1983; Wright et al. 1992; Rietkerk et al. 2004; Eppinga et al. 2009; Harris et al. 2020). The apparent complexity in pattern formation and in the feedback between formation mechanisms coupled with varying physiographic settings give rise to the observed variety of peatland patterning or the lack thereof. As such, predicting where patterned fens may occur is not always straightforward, and small patterned fens may continue to be discovered with easily accessible, aerial imagery. Patterned fens are imperiled in Michigan, and their status is unknown globally (Kost et al. 2007; NatureServe 2021). They provide habitat for a unique suite of plants, including several rare species that occur primarily in the community, and a wide variety of animal species (Wheeler et al. 1983; Berg 1992; Glaser 1992b; Karns 1992; Niemi and Hanowski 1992; Nordquist 1992; Slaughter and Cohen 2010). Continued efforts to document and describe this rare and unique peatland type are merited.

ACKNOWLEDGMENTS

AG would like to thank a group of friends: Rob Routledge, Brad Von Blon, Nathan Martineau, McKenna Deal, and Veronique Tessier, for humoring the unrelenting desire to navigate through challenging terrain to access various peatlands. JC would like to thank Dennis Albert, Mike Penskar, Michael Kost, and Bradford Slaughter (the quintessential marl trotter) for their years of work surveying and describing Michigan's peatlands. We also thank Rob Routledge and Emily Mydlowski, who so generously dedicated their time in reviewing the manuscript.

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IN MEMORIAM—DON C. HENSON

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Don C. Henson passed away at his home in Manistique, Michigan on Saturday, December 26, 2020, at the age of 75.

Don was born at Henderson Air Force Base, Nevada, on July 27, 1945 to Don C. and Julie A. (Murdoch) Henson. Don earned his Bachelor of Arts degree in Anthropology from the College of Liberal Arts, Southern Illinois University, Carbondale, class of 1970. He married Martha Jane Pinkstaff in St. Francisville, Louisiana, on June 11, 1967. During his college studies, Don also took a botany class from Dr. Robert H. Mohlenbrock, a well-known Midwestern floristics specialist, this formal exposure to plant diversity undoubtedly providing both the foundation and impetus to his later exploration of Michigan's Upper Peninsula. Don and Jane served in the Peace Corps in Sierra Leone from 1967 to 1969. The couple moved to Manistique, Michigan, in 1970 after their Peace Corps stint, when Jane took a teaching job with Manistique Area Schools. Don began collecting plants in the Upper Peninsula as they came into bloom in the spring of 1971 and continued as long as he was able.

Though he contributed extensively to the Michigan Flora and was active in the Michigan Botanical Club, Don's interests were multifaceted. He was self-employed as a well-known artist, painting and exhibiting regionally through his Tamarack Studios. He specialized in the *trompe l'oeil* (meaning "deceive" or "fool the eye") painting technique, in which he was heavily influenced by the famous Irish-American painter William Michael Harnett. To employ this style, Don painstakingly constructed elaborate models of his scenes in his tiny studio, these depictions often incorporating artifacts (e.g., old duck decoys, enamelware plates, and pails) he encountered in old logging camps and similar places while conducting botanical surveys. His art thus meshed with his natural history interests. He was successful in a number of juried shows, particularly at the renowned Leigh Yawkey Woodson Art Museum in Wausau, Wisconsin. Here, Don participated in the yearly show of bird paintings, Birds in Art; where a jury selected about 100 bird paintings from artists around the world for the exposition. He regularly participated from 1981 through 1991, missing only 1986, 1988, and 1989.



FIGURE 1. Don Henson. Undated photo, courtesy of Paul Pinkstaff.

Don and Jane also collected antique glass, and throughout his life he also maintained an interest in anthropology and archeology.

Don's botanical work was confined to the Upper Peninsula. He famously resisted crossing over the Mackinac Bridge to visit the Lower Peninsula, or driving in densely populated areas. But despite this, he collected intensively, with nearly 4000 specimens recorded in the Michigan Flora data and deposited in the University of Michigan Herbarium (MICH). This places him firmly in the top 10 for collections by Michigan botanists, and second only to the indefatigable Ed Voss for Upper Peninsula collections. Oddly enough, Don missed botanizing on the two large islands geographically bracketing the Upper Peninsula—Isle Royale and Drummond Island.

Don was a legend in Michigan botany, tremendously knowledgeable, sensitive to unusual habitats and plant associations, and with an uncanny ability to find rare plants. Among the native plants he added to Michigan's flora from the Upper Peninsula were boreal species like *Carex heleonastes* L.f., *Petasites sagittatus* (Pursh) A. Gray, and *Rubus acaulis* Michx., more western elements like

Erythranthe guttata (DC.) G. L. Nesom (*Mimulus guttatus*), *Rumex occidentalis* S. Watson, and the prairie species *Asclepias ovalifolia* Decne. in the western Upper Peninsula, and species more at home in the eastern North American forests and bogs like *Bartonia paniculata* (Michx.) Muhl., *Carex novae-angliae* Schwein., and *Omalotheca sylvatica* (L.) Sch. Bip. & F.W. Schultz. Though he was most interested in native plants, he did not shirk aliens and added a few to the Michigan Flora, even from the relatively less developed Upper Peninsula. His wife Jane was a steadfast partner in his botanical efforts, occasionally accompanying him botanizing, and often pressing the many plant specimens he collected, in addition to typing the numerous labels required for these extensive and important collections.

With his vast knowledge of Upper Peninsula plants and localities, Don helped many students and botanists, professional and amateur, with plant localities and field work in the Upper Peninsula. Don especially helped Herb and Florence Wagner find *Botrychium* sites, helped one of us (AAR) many times with *Carex* field studies, Fred and Roberta Case with their orchid studies, and regularly accompanied Ed Voss in the field. He also frequently helped Michigan Natural Features Inventory (MNFI) botanists and ecologists with Upper Peninsula field work and obtained several contracts through that program for taking part in important survey efforts. The other of us (MRP) worked extensively with Don in many areas conducting rare plant and natural community inventories, including in places such as the Huron Mountain Club, remote forests, vast peatland complexes, and numerous Great Lakes shoreline sites along Lakes Huron, Michigan, and Superior. He also conducted rare plant species surveys for the U.S. Forest Service (USFS), primarily in the Hiawatha National Forest, to determine the presence of listed plant species, largely in areas proposed for timber cutting or similar activities with potential impacts. Along with one of us (AAR), Don served on a Research Natural Area (RNA) committee for the Hiawatha National Forest to identify and propose important USFS land tracts for RNA consideration. The selection of several candidate areas for investigation was an important task, and several of these candidate sites have now been formally dedicated. Most especially, Don was an ardent conservationist and defender of the environment and biodiversity of the Upper Peninsula, and worked with and advised several advocacy groups both within and outside Michigan.

One of Don's important contributions was showing special Upper Peninsula habitats to Robert Mohlenbrock, who featured three of them in his popular column "This Land," which ran for a number of years in Natural History Magazine. These three, the Summerby Swamp, the Shingleton Bog, and the savannas at Shakey Lakes, appeared in Natural History 103(3): 20–22, 103(4): 20–22 (1994), and 104(3): 22–24 (1995) respectively. This brought national attention to these special habitats and the rare plants that they contained.

Don's botanical focus was field work, and this, plus the lack of any institutional underpinnings, meant his publications were limited. He did publish on some of the rarest plants he discovered and he contributed his knowledge of Upper Peninsula plants over several review cycles for the Michigan rare plant listings. One of the groups in which he had a special interest was *Botrychium*, and he also contributed to a substantial article on these.

Don was preceded in death by his parents and his wife, M. Jane Henson. Surviving are his two sisters, Sue Anne (Dave) Fones of Seymour, Illinois and C. Jane (Paul) Pinkstaff of Livonia, Michigan.

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EPONYMY

×*Calammophila don-hensonii* Reznicek & Judz.
Calamagrostis ×*don-hensonii* (Reznicek & Judz.) Saarela

ACKNOWLEDGMENTS

Thanks to Gijsbert van Frankenhuyzen and Robbyn Smith van Frankenhuyzen for providing details about Don Henson's art.

NOTEWORTHY COLLECTION

WESTWARD RANGE EXTENSION OF *DENDROLYCOPodium* *OBSCURUM* (L.) A. HAINES (LYCOPODIACEAE), INCLUDING NEW STATE RECORDS FOR MINNESOTA, U.S.A.

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Significance of the Report. A westward extension of the species' range, including new state records for the state of Minnesota.

Previous Knowledge. The genus *Dendrolycopodium* A. Haines (Lycopodiaceae) (ground-pine), which is a small genus that has been segregated from the larger genus *Lycopodium* L. (Haines 2003; PPG I 2016), consists of four species, three of which are known from the Great Lakes region (Wagner Jr. and Beitel 1993). The fourth species in the genus, *D. juniperoideum* (Sw.) A. Haines, is found in northeast Asia. The three Great Lakes species—*D. dendroideum* (Michx.) A. Haines, *D. hickeyi* (W.H. Wagner, Beitel & R.C. Moran) A. Haines, and *D. obscurum* (L.) A. Haines—have all been documented from the state of Wisconsin. Various online resources and field guides (Chadde 2019; Kartesz 2015; USDA, NRCS 2020; Walewski 2016) show all of these species as also occurring in the state of Minnesota. However, our thorough examination of *Dendrolycopodium* collections in Minnesota's major herbaria indicates that all specimens are either *D. dendroideum* or *D. hickeyi*.

In addition to the herbarium review, we also reviewed observations of *Dendrolycopodium obscurum* in Minnesota from the iNaturalist internet platform (iNaturalist 2020). Most observations were incorrectly identified, and the others lacked photographic evidence of the necessary characteristics for identification. We made field visits to the sites of reported observations of *D. obscurum*, but found only *D. dendroideum* or *D. hickeyi*.

Discussion. In the fall of 2019, we began discussing the possibility of finding *Dendrolycopodium obscurum* in Minnesota. During a visit to the Wisconsin State Herbarium (WIS) at the University of Wisconsin-Madison, we examined specimens of *D. obscurum* collected from Wisconsin counties bordering Minnesota. We found that a few collections from Douglas County were correctly identified (Figure 1, triangles symbols). We then contacted other

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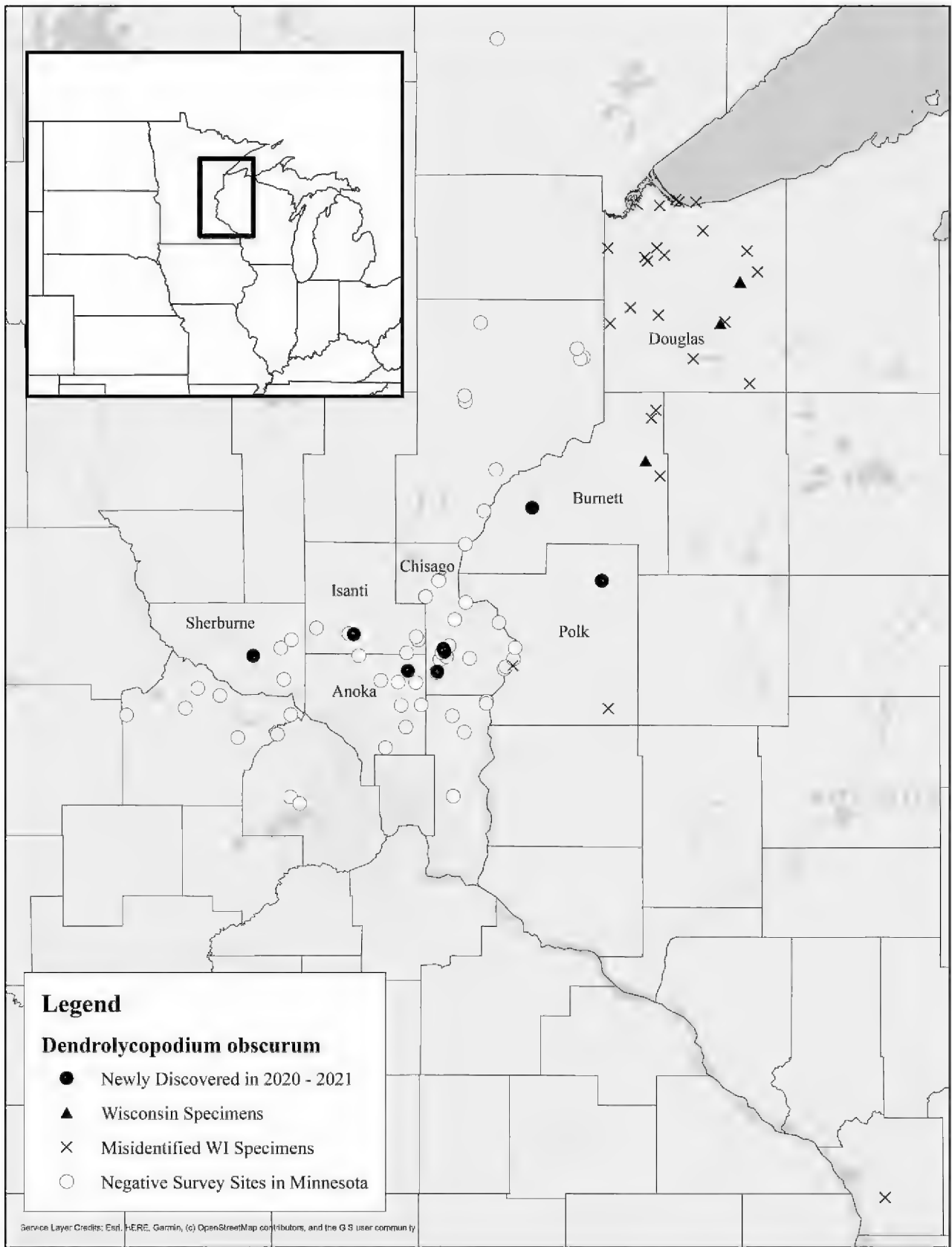


FIGURE 1. Inset: Location of study area in upper Midwest. Main map: the western distribution of *Dendrolycopodium obscurum* (L.) A. Haines. Triangles represent past herbarium collections correctly identified as *D. obscurum*. X represents past herbarium collections that were either misidentified or were not *D. obscurum* in the strict sense. Black circles represent collection sites of newly discovered populations in 2020 and 2021, and hollow circles represent sites where *D. obscurum* was not found. The map shows Wisconsin collection data only from counties bordering Minnesota.

herbaria in Wisconsin with reported collections of *D. obscurum* from bordering counties to get a better understanding of its western distribution. We found 36 collections from four Wisconsin counties bordering Minnesota in four herbaria (UW-Madison, UW-Stevens Point, UW-Superior and Milwaukee Public Museum) that had been identified as *D. obscurum*. Thirty-two of the 36 collections were either misidentified or were not *D. obscurum* in the strict sense (Figure 1, “X” symbols).

During the late summer of 2020 and into the spring of 2021, we conducted field studies to determine whether *Dendrolycopodium obscurum* is actually present in Minnesota. We were inspired by two discoveries of *D. obscurum* we made in western Wisconsin earlier in the 2020 season. The first was a population found in northeastern Polk County in a mesic hardwood forest dominated by *Tilia americana* and *Quercus rubra*. The second was a population in western Burnett County in a dry mesic woodland dominated by *Quercus ellipsoidalis* and with an understory of *Acer rubrum*. This second population was approximately 17 km from the Minnesota border.

We targeted 60 sites in eastern Minnesota as potential localities for *Dendrolycopodium obscurum*. We found five populations (Figure 1, black circles), one each in Anoka County, Isanti County, and Sherburne County, and two in Chisago County. These populations were in forests and woodlands similar to the habitat of the population found in western Burnett County, Wisconsin. We were unable to locate *D. obscurum* at any of the other 55 sites we surveyed (Figure 1, hollow circles).

Finally, we used this information to correct the misidentification of *Dendrolycopodium obscurum* observations in Minnesota on the iNaturalist platform, where possible. We also provided updates to the county distribution maps on the Biota of North America Project (Kartesz 2015), with the hope that other future projects that use these data will more accurately reflect the distribution of *D. obscurum* in Minnesota.

Diagnostic Characters. *Dendrolycopodium obscurum* and *D. hickeyi* each have ascending to appressed main stem leaves (trophophylls), and their lateral branch leaves are arranged in six ranks of one dorsal, one ventral, and two on each lateral side. *Dendrolycopodium obscurum* is unique in having its ventral leaves smaller in size than the other ranks (Hickey 1977) (Figure 2). The dorsal and ventral leaves are ascending to appressed, giving the lateral branches a flattened appearance in cross section, whereas the equal-sized, spreading-ascending leaves of *D. hickeyi* give its lateral branches a rounder aspect. *Dendrolycopodium dendroideum* differs in its stiff, spreading main stem leaves and lateral branches that have leaves arranged in two dorsal ranks, two ventral ranks, and one lateral rank on each side (Hickey 1977).

Specimen Citations. WISCONSIN. POLK COUNTY. McKenzie Creek Wildlife Area. About 13.5 km east-southeast of Frederic. About 1.8 km (as crow flies) south-southwest of Ice Age Trail parking lot on Cty. Rd. W. 45.62280°N 92.30164°W. Apparently rare and local in mesic hardwood forest above McKenzie Creek. 2m x 4m patch in mesic to dry-mesic hardwood forest dominated by *Quercus rubra*, *Tilia americana*, occasional *Carya cordiformis*. Canopy 50–60% cover. Shrub layer with *Ostrya virginiana*, *Acer rubrum*, *Carpinus caroliniana*.



FIGURE 2. Ventral view of a branch of *Dendrolycopodium obscurum* (L.) A. Haines. The reduced leaves (trophophylls) on the underside of the branch are appressed and contribute to the flattened appearance of the branches in this species. Photo by Richard W. Haug.

Associated species include *Diphasiastrum digitatum*, *Osmorhiza claytonii*, *Uvularia sessilifolia*, *Trillium grandiflorum*, *Carex pensylvanica*. May 6, 2020. Derek S. Anderson 2985 (MIN).

WISCONSIN. BURNETT COUNTY. Crex Meadows Wildlife Area. East of North Fork Flowage and north of North Fork Dike Road. 45.83036°N 92.58549°W. Dry-mesic woods with canopy of *Quercus ellipsoidalis* and understory of *Acer rubrum*. 3 × 6 meter patch occurring near margin of ephemeral woodland pool. Additional small patches nearby. Associated with *Uvularia sessilifolia*, *Maianthemum canadense*, *Trientalis borealis*, *Dryopteris carthusiana* and *Viola* sp. August 3, 2020. Richard W. Haug 330 (WIS).

MINNESOTA. ISANTI COUNTY. Marget Lake Wildlife Management Area. About 4 km southwest of Isanti. 45.47010°N 93.31320°W. Dry deciduous woods with canopy of *Quercus ellipsoidalis* and understory of *Acer rubrum*. 1 × 2 meter patch on slight, north-facing slope 10 meters from small sedgy wetland. Sparse flora on forest floor, associated with *Viola sp.* September 5, 2020. Richard W. Haug 401 (MIN).

MINNESOTA. ISANTI COUNTY. Marget Lake Wildlife Management Area. About 4 km southwest of Isanti. 45.47027°N 93.31294°W. Dry deciduous woods with canopy of *Quercus ellipsoidalis* and understory of *Acer rubrum*. 5 × 8 meter patch, associated with *Osmunda regalis*, *Onoclea sensibilis*, *Dryopteris carthusiana*, *Viola sp.* and seedlings of *Frangula alnus*. September 5, 2020. Richard W. Haug 402 (MIN).

MINNESOTA. SHERBURNE COUNTY. Uncas Dunes Scientific and Natural Area. About 8 km northeast of the city of Big Lake. 45.40856°N 93.72227°W. Dry deciduous woods of smaller-sized *Quercus ellipsoidalis*, *Quercus macrocarpa* and *Populus tremuloides*. Shrub layer of occasional *Corylus americana*, *Vaccinium angustifolium* and seedlings-saplings of *Acer rubrum*. 4 × 5 meter patch 20 meters from edge of sedge meadow. Associated with *Carex pensylvanica* and *Trientalis borealis*. October 2, 2020. Richard W. Haug 450 (MIN).

MINNESOTA. ANOKA COUNTY. Martin-Island-Linwood Lakes Regional Park. Along southeast shore of Island Lake, south of the parking lot and swimming beach. 45.36588°N 93.09226°W. Stems are densely clustered to scattered in an area 7 × 15 meters, in a mixed woods 25 meters from the lake shore. Sparse super canopy of mature *Pinus strobus*. Canopy of *Quercus rubra*, *Q. ellipsoidalis*, *Q. alba* and *Populus grandidentata*. Understory of young *Pinus strobus*. Associated with *Juniperus communis* and *Lycopodium clavatum*. November 2, 2020. Richard W. Haug 471 (MIN). (Figure 3).

MINNESOTA. CHISAGO COUNTY. Carlos Avery Wildlife Management Area. About 4 km northeast of Stacy. 45.41874°N 92.94526°W. Gently rolling topography. Woodland/forest dominated by *Quercus ellipsoidalis*, *Betula pumila*, *Prunus serotina* and *Acer rubrum*. Slight north to northeast-facing slope above small ephemeral wetland. *Vaccinium angustifolium* common in shrub layer. Plants diffuse with occasional dense patches in 5 × 5 meter area. Associated species include *Carex pensylvanica*, *Lycopodium clavatum*. March 13, 2021. Derek S. Anderson 3467 (MIN, WIS).

MINNESOTA. CHISAGO COUNTY. Sunrise Unit of Carlos Avery Wildlife Management Area. About 3 km northeast of the town of Wyoming. 45.36299°N 92.97240°W. Plants are spread in a 3 × 10 m area in sandy, nearly level ground on an elevated, wooded “island” overlooking the South Branch Sunrise River. Canopy of younger *Quercus ellipsoidalis*, *Q. macrocarpa*, *Q. alba*, *Betula papyrifera*, *Prunus serotina*. Associated species include *Carex pensylvanica*, *Huperzia lucidula*, *Lycopodium clavatum*. March 13, 2021. Richard W. Haug 472 (MIN).



FIGURE 3. Habit of *Dendrolycopodium obscurum* (L.) A. Haines. This individual was in a population near Island Lake in Anoka County, Minnesota, growing in a mixed wood with a sparse super canopy of *Pinus strobus* and a canopy of *Quercus rubra*, *Q. ellipsoidalis*, *Q. alba*, and *Populus grandidentata*. Photo by Richard W. Haug.

ACKNOWLEDGMENTS

We would like to extend a thank you to the individuals and institutions that reviewed their *Dendrolycopodium obscurum* collections from counties bordering the state of Minnesota. This includes Dr. Robert Freckmann, Professor Emeritus, Robert W. Freckmann Herbarium UW-Stevens Point (UWSP); Dr. Christopher Tyrell, Research Curator, Milwaukee Public Museum (MIL); Mr. Paul Hlina, retired researcher, Donald W. Davidson Herbarium, UW-Superior (SUWS); and Dr. Mary Ann Feist, Senior Academic Curator, Wisconsin State Herbarium (WIS). We would also like to thank the editor, Michael Huft, and two anonymous reviewers for their comments to help improve this article.

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BOOK REVIEW

John R. Tester, Susan M. Galatowitsch, Rebecca A. Montgomery, and John A. Moriarty. 2020. *Minnesota's Natural Heritage*, Second edition. University of Minnesota Press, Minneapolis, London. xvi + 472 pp. hardcover. ISBN 978-1-5179-0357-2. \$49.95.

Chel Anderson and Adelheid Fischer. 2014. *North Shore: A Natural History of Minnesota's Superior Coast*. University of Minnesota Press, Minneapolis, London. xii + 620 pp. hardcover. ISBN 978-0-8166-3232-9. \$39.95.

These two large coffee table-sized books are richly illustrated and contain a wealth of information about Minnesota's natural history. The second edition of **Minnesota's Natural Heritage** is a revision published 25 years after the original book, which was written by the first author alone. The heart of the book consists of six chapters that each covers a major community type—deciduous forests, northern coniferous forests, tallgrass prairies, wetlands, lakes, and streams and rivers. Each of these chapters has extensive discussions of the ecology and natural history components of the community, often broken down into subtopics. For example, the tallgrass prairie chapter describes the vegetation of the prairie, first in general terms including the various functional groups, such as warm-season perennial grasses, cool-season annual grasses, legumes, late-flowering perennial forbs, and several others, then describes more specifically the vegetation of different types of prairies, such as mesic, dry, wet, and savannas. Also included are discussions of the effects of fire and of grazing, characteristics of the prairie-forest border, and descriptions of ecosystem processes such as biomass production, creation of prairie soil, productivity, and mineral recycling. Additional extensive sections describe the various groups of animals present—mammals, birds, amphibians and reptiles, and insects—and their effect on the ecology and vegetation of the prairie. Each of the remaining chapters devoted to community types contains similar material. But these chapters are not limited to description—each of them concludes with accounts of past and present conservation efforts, trends in degradation, and discussion of restoration projects and management practices.

These community chapters are preceded by three initial chapters that set the stage, so to speak, by giving an account of the geological history and present landscape of Minnesota and of its climate and weather and concluding with a brief introduction to the principles of ecology. These principles include energy flow, food webs, nutrient cycling, productivity, population dynamics, species interaction, and disturbance and succession. A final chapter is devoted to future prospects, including dealing with habitat loss, sustainable human population growth, the effect of the climate change, managing invasive species, dealing with chemical pollution, and the preservation of endangered species. Several ap-

pendices add value by listing the mammals, breeding birds, amphibians and reptiles, fish, trees and shrubs, and common herbs found in Minnesota.

North Shore is an in-depth exploration of that portion of Minnesota that lies north of Lake Superior, in other words, primarily Cook, Lake, and St. Louis Counties. Nearly all of this area consists of state, federal, or tribal land, including Superior National Forest, Boundary Waters Canoe Area Wilderness, several state parks, and the Grand Portage Indian Reservation, all covered with magnificent boreal forest and north woods. This book does full justice to the geological history and biological diversity of the area, nor does it omit the interesting human history.

The book is divided into five sections: (i) Headwaters, which is the area furthest inland where the principal rivers and streams that flow into Lake Superior arise; (ii) Highlands, which encompasses the Highland Moraine and other bedrock ridges lying parallel to the shore; (iii) Nearshore, the terrestrial area along the shore; (iv) Lake Superior, which treats the lake in its entirety; and (v) Islands, which includes those nearby islands such as Isle Royale and the Susie Islands that share geological and botanical features with the mainland.

Within these five major sections is a wealth of material on history, both human and natural, interesting accounts of various organisms, such as salamanders, diatoms, chorus frogs, black bears, pitcher plants, bird diversity, moose and wolves on Isle Royale, history of botanical exploration, and water circulation in Lake Superior, to name just a few of the many topics explored in depth. There are many beautiful maps, and many more wonderful photographs and drawings.

A lengthy epilogue explores the deleterious effect of climate change on each of the five ecological areas after presenting the general principles of climate change and follows this with suggestions for future action. Each of the five sections and the epilogue contain a list of suggested further readings.

Together, these two books provide the reader with a superb general coverage of Minnesota's natural history and will serve as welcome companions during a lifetime of exploration throughout the state.

—Michael Huft